Serials
QH
1
.S69
v.107
no.1
24116-120

ISSN 0038-3872

SOUTHERN CALIFORNIA ACADEMY OF SCIENCES

BULLETIN

Volume 107 Number 1

BCAS-A107(1) 1–44 (2008) April 2008

SHOUT
SHARE
IT

Southern California Academy of Sciences

Founded 6 November 1891, incorporated 17 May 1907

CALIFORNIA
ACADEMY OF SCIENCES
MAY 30 2008
LIBRARY

OFFICERS

Brad Blood, *President*
Judith Lemus, *Vice-President*
John Roberts, *Secretary*
Daniel A. Guthrie, *Treasurer*
Daniel A. Guthrie, *Editor*
Ralph G. Appy, *Past President*
Robert Grove, *Past President*
Daniel J. Pondella, II, *Past President*
John H. Dorsey, *Past President*

BOARD OF DIRECTORS

2005–2008	2006–2009	2007–2009
Jonathan N. Baskin	M. James Allen	Brad R. Blood
John Roberts	Sabrina Drill	Julianne Kalman
Gloria J. Takahashi	Judith Lemus	Jerry Scnubel
Andrea Murray	Darren Sandquist	Kathy Keene
Phillippa Drennan	SusanYoder	Edith Reed

Membership is open to scholars in the fields of natural and social sciences, and to any person interested in the advancement of science. Dues for membership, changes of address, and requests for missing numbers lost in shipment should be addressed to: Southern California Academy of Sciences, the Natural History Museum of Los Angeles County, Exposition Park, Los Angeles, California 90007-4000.

Professional Members	$45.00
Student Members	25.00

Memberships in other categories are available on request.

Fellows: Elected by the Board of Directors for meritorious services.

The Bulletin is published three times each year by the Academy. Manuscripts for publication should be sent to the appropriate editor as explained in "Instructions for Authors" on the inside back cover of each number. All other communications should be addressed to the Southern California Academy of Sciences in care of the Natural History Museum of Los Angeles County, Exposition Park, Los Angeles, California 90007-4000.

Date of this issue 28 April 2008

♾ **This paper meets the requirements of ANSI/NISO Z39.48-1992 (Permanence of Paper).**

Bull. Southern California Acad. Sci.
107(1), 2008, pp. 1–24

A Review of the Physical and Biological Characteristics of the Bahía Magdalena Lagoon Complex (Baja California Sur, Mexico)

Joseph J. Bizzarro

Pacific Shark Research Center, Moss Landing Marine Laboratories, 8272 Moss Landing Rd., Moss Landing, CA 95039, jbizzarro@mlml.calstate.edu

Abstract.—The Bahía Magdalena lagoon complex (BMLC) is an extremely productive and biologically diverse embayment on the Pacific coast of Baja California Sur, Mexico, and one of the most important fishing ports in the state. Local hydrologic conditions are largely determined by the differential influence of the California Current and California Countercurrent, with upwelling also affecting the physical characteristics of west–central Bahía Magdalena. Because of its subtropical location and variable hydrology, the BMLC is considered a transitional zone between temperate and tropical faunal regions. Tropical species are dominant among most taxa, especially in Bahía Almejas, but species composition is highly variable and coupled with environmental conditions.

The geographic orientation and physical characteristics of the Bahía Magdalena lagoon complex (BMLC), located on the Pacific coast of Baja California Sur (BCS), Mexico (Fig. 1), combine to create a contiguous system of shallow canals, intertidal sand flats, and embayments that is highly productive and biologically diverse (Alvarez–Borrego et al. 1975; Nienhuis and Guerrero–Caballero 1985; Cruz–Agüero et al. 1994). Because of its subtropical location, intermittently dominant current regimes (California Current and California Countercurrent), and seasonal upwelling (Bakun and Nelson 1977; Ibarra–Obando et al. 2001), the BMLC is situated at a transitional zone between temperate and tropical faunal regions (Briggs 1974; Brusca 1980). A great variety of marine flora (Sánchez–Rodríguez et al. 1989; Gárate–Lizárraga et al. 2001) and fauna (Castro–Aguirre and Torres–Orozco 1993; Félix–Pico and García–Domínguez 1993) therefore occupies this region as either eurythermal resident species or seasonal transients.

The shallow, protected waters of the BMLC are also typically warmer, more quiescent, and more productive than adjacent offshore waters (Acosta–Ruíz and Lara–Lara 1978; Obeso–Nieblas et al. 1999; Lluch–Belda et al. 2000), creating prime nursery conditions for a variety of vertebrate and invertebrate taxa, including: crabs (Sánchez–Ortiz and Gómez–Gutiérrez 1992), shrimps (Flores–Castanon 1980), bony fishes (Castro–Barrera 1975; Gutiérrez–Sánchez 1997), elasmobranchs (Guardado–France 1976; Villavicencio–Garayzar 1995; Bizzarro et al., 2007), and marine mammals (Rice et al. 1981; Ramírez–Espinosa 1990; Chaves–Rosales and Gardner 1999). Eelgrass (*Zostera marina*) and surfgrass (*Phyllospadix torreyi*) reach their southern limit at the BMLC (Riosmena–Rodríguez and Sánchez–Lizaso 1996; Santamaría–Gallegos et al. 2003). Mangroves also replace salt marshes as the dominant littoral vegetation in this region (Brusca 1980; Ibarra–Obando et al. 2001). Both seagrass beds (e.g., McRoy and Helfferich 1977; Connolly 1994) and mangrove prop roots (e.g., Robertson and Duke 1987; Morrissey and Gruber 1993) provide habitat and nursery functions for a great variety of species, thereby further enhancing nursery potential and biodiversity of the BMLC.

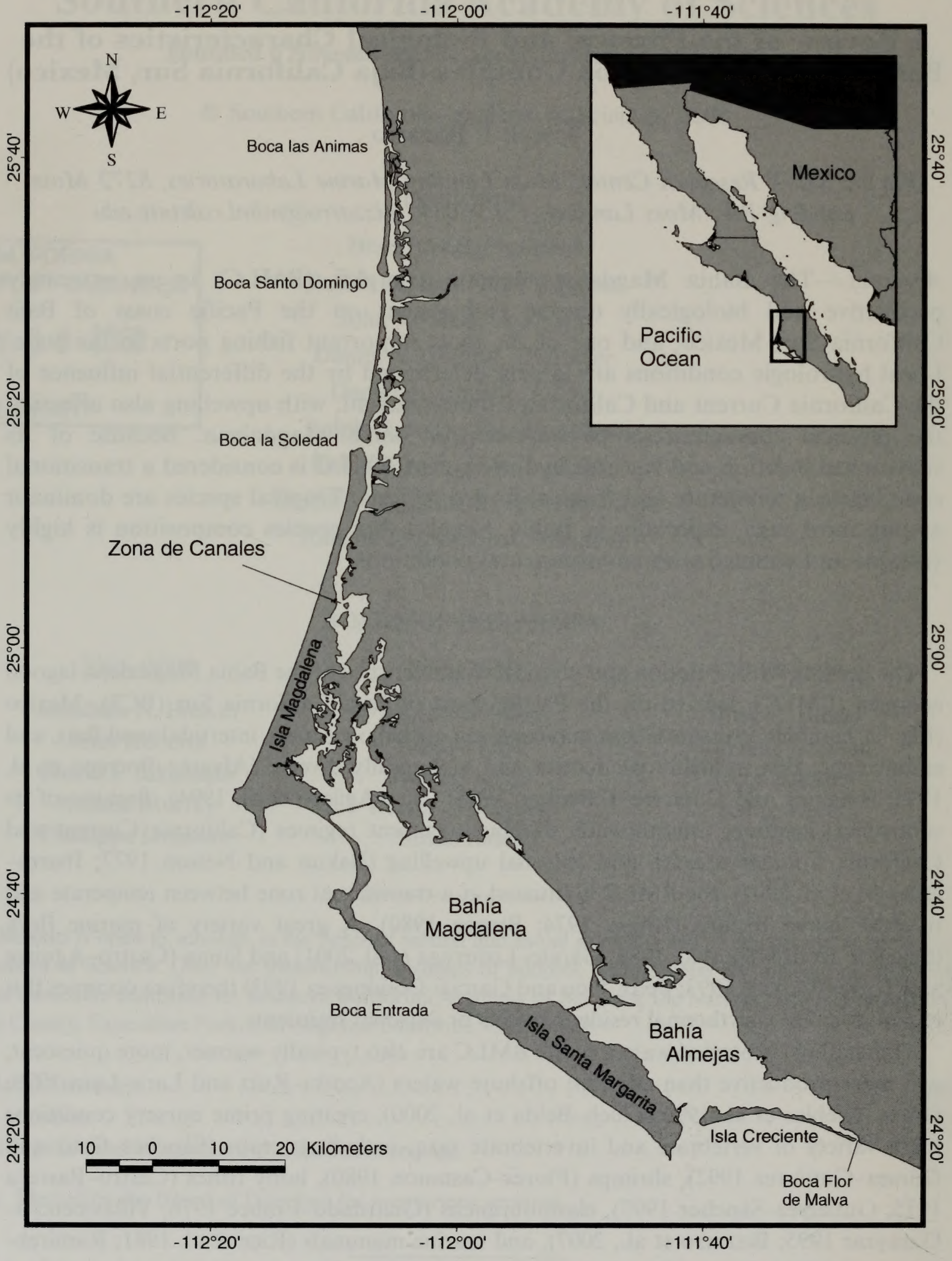

-112°20'
-112°00'
-111°40'
N
W
E
S
25°40'
25°20'
25°00'
24°40'
24°20'
Mexico
Pacific
Ocean
Boca las Animas
Boca Santo Domingo
Boca la Soledad
Zona de Canales
Isla Magdalena
Bahía
Magdalena
Boca Entrada
Isla Santa Margarita
Bahía
Almejas
Isla Creciente
Boca Flor
de Malva
10 0 10 20 Kilometers

Fig. 1. The Bahía Magdalena lagoon complex, located on the Pacific coast of Baja California Sur, Mexico (see inset map). Dashed lines represent boundaries between regions.

Because of its considerable productivity, the BMLC contains abundant populations of several commercially harvested invertebrates and fishes and is considered one of the most important fishing ports in BCS (Cruz–Agüero et al. 1994; Obeso–Nieblas et al. 1999). Both industrial (Casas–Valdez 1987; Robinson et al. 2000) and artisanal (Gutiérrez–Uribe 1987; Rámirez–Rodríguez 1987; Salazar–Hermoso and Villvicencio–Garayzar 1999) fisheries occur in local waters. Large vessels (barcos) typically operate out of Puerto San Carlos, northern Bahía Magdalena or Puerto Adolfo López Mateos, Zona de Canales (Félix–Uraga et al. 1996), but a processing plant has also been active historically at Puerto Alcatraz in Bahía Almejas (Casas–Valdez 1987). Artisanal fishermen use small fiberglass vessels (pangas) and reside among the many coastal towns and fishing camps within the BMLC (pers. obs.).

Although the BMLC is of great biological and economic importance, limited historical information is available from this region and no comprehensive account of its physical and biological properties has been published. A Japanese researcher produced the first known scientific work from the BMLC, a 1913 technical report detailing fishery resources (especially abalones, *Haliotis fulgens*, *H. corrugata*, and spiny lobsters, *Panulirus interruptus*, *P. inflatus*) of Bahía Magdalena (Takasaki 1913). This report, however, was unknown to the western scientific community until Chapa–Saldaña published a translated version in 1962. Although both Japanese and Mexican fisheries operated in this area during the early and mid 1900s, additional relevant scientific publications were essentially limited to biological and taxonomic descriptions of local organisms (e.g., Dall 1918; Bartsch and Rehde 1939; Beebe and TeeVan 1941a, b). Knowledge expanded greatly in the mid–1970s, however, as several seminal studies concerning hydrology (Alvarez–Borrego et al. 1975; Acosta–Ruíz and Lara–Lara 1978), potential fisheries (Matthews and Druck–Gonzalez 1974 a, b; Mathews and Espinoza 1974; Mathews and Guardado–France 1974), and socio–economic development (Mathews 1975) were published.

Based on the interest generated by these publications and the increasing biological and economic importance of this region, the Mexican scientific community began to focus attention on the BMLC. The Centro Interdisiplinario de Ciencias Marinas (CICIMAR; La Paz, BCS) established a hydrological monitoring program in 1980 and has since become a primary source for scientific information about this region. Scientists and researchers from the Universidad Autónoma de Baja California Sur (UABCS; La Paz, BCS) also have published several studies in recent years and conduct ongoing research in the BMLC. To date, more than 100 scientific papers describing physical or biological characteristics and fisheries of this region have been published. Most of these works are printed in Spanish–language journals by Mexican authors, but English–language publications and American researchers have become more frequent. Many undergraduate and graduate theses projects also have been conducted in the BMLC, with the great majority completed by students from UABCS and CICIMAR, respectively.

The objective of this study is to describe the physical and biological characteristics of the BMLC, based principally on a comprehensive review of pertinent scientific literature. Supplemental information pertains mainly to Bahía Almejas and was provided through personal observations, Geographic Information Systems (GIS) spatial analysis methods, and analysis of sediment samples. This review is intended primarily for use by marine scientists, naturalists, and resource managers to provide a better understanding of the extent of historical work conducted in the region and to hopefully stimulate the development of future research projects.

Materials and Methods

The majority of the information used in this review was compiled from published scientific literature describing physical and biological characteristics of the BMLC. The following search engines were initially used to locate citations: Aquatic Sciences and Fisheries Abstracts, GeoRef, Biosis, Web of Science, and Zoological Record. After relevant manuscripts were obtained, their literature cited sections were perused for

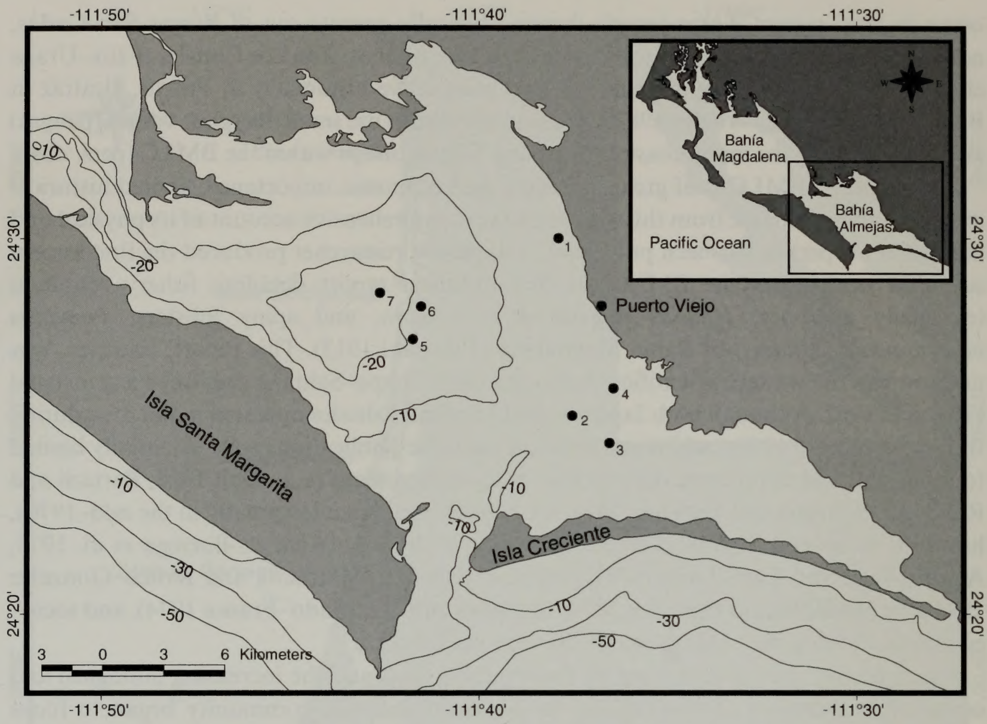


Fig. 2. Bathymetry profile of Bahía Almejas and surrounding regions, including location of sediment samples. Isobath values are listed in meters.

additional references. Mexican colleagues from CICIMAR, the Instituto Nacional de la Pesca, and the Centro de Investigación Cientifica y Educación Superior de Ensenada were also contacted to obtain supplemental literature that may have been overlooked during previous searches, especially unpublished Mexican theses. Pertinent literature was accumulated and examined, regardless of publication language. Abstracts from conference proceedings were used when peer–reviewed publications were unavailable. Personal observations made primarily in Bahía Almejas during summer months (June–August) from 1998–2002 were incorporated as deemed appropriate.

Geographic Information Systems technology, specifically ArcView® and ArcGIS® software, was used to determine surface area of the three BMLC regions (i.e., Zona de Canales, Bahía Magdalena, and Bahía Almejas) and depth zonation within Bahía Almejas (Environmental Systems Research Institute 2002a, b). A 1998 nautical chart produced by the National Imagery and Mapping Agency (NIMA) was scanned and georeferenced to create a derivative digital file. Bathymetry contours were digitally transcribed from this file in ArcView® v3.3 to create contour polygons at 10 m intervals for Bahía Almejas and at 20 m for the adjacent offshore region. Spatial analysis was then performed to estimate depth–specific area within Bahía Almejas. Similarly, distinct polygons were created for each BMLC region using the Mexican states shapefile available from ArcGIS® v8.2 and subsequently used to estimate region–specific area.

Sediment samples were collected in Bahía Almejas on 22 and 23 August 1999. Thirty sampling locations were randomly selected and were then grouped based on relative proximity to facilitate efficient data collection. Only the first three groups, representing seven locations (Fig. 2), were sampled as a result of logistic problems encountered during fieldwork. Three replicate sediment samples were collected manually at each location, using SCUBA when necessary, with cores constructed from coffee cans of 10.0 cm diameter and 13.7 cm height. Penetration of most cores was 8–10 cm.

Sediment samples were analyzed for grain size using procedures and protocol modified from Folk (1974). Sediments were desiccated for 24 hours at 60°C in a drying oven, weighed, and visually inspected. Samples containing mud were additionally processed by adding 50 ml of de–ionized water and a 10 ml solution of 50 g/L dishwashing soap to facilitate de–flocculation of clays. These clay–enriched samples were then placed on a rotary table at 110 rpm for 24 hours to disaggregate clay clasts and wet sieved through a 38 μm (6ϕ) screen. The remaining fraction (> 38 μm) was dried for an additional 24 hours and re–weighed. The difference between original and post–processing weights was used to determine the weight of mud removed from the samples.

The retained sediment (> 38 μm) for each sample was shaken in a mechanical Roto–Tap for 15 minutes to separate clasts. Sets of three incrementally finer sieves (>125 μm, >63 μm, and >38 μm) were used were used to sort sediment by grain size. Based on the relative weight of each grain size category, samples were classified using the Wenthworth sedimentary grade scale (Wentworth 1922). Estimates of sediment sorting, a measure of the uniformity of sediment clast size, were determined visually based on an illustration from Boggs (2001). The predominant mineral grains of the sediment samples were identified using a dissecting microscope.

Results and Discussion

Physical description and bathymetry

The BMLC is located on the Pacific coast of Baja California Sur, beginning ~900 km southeast of the U.S./Mexican border (Fig. 1). It is the largest embayment on the west coast of the Baja peninsula, spanning between 24° 20′ and 25° 44′ N and 111° 27′ and 112° 15′ W, a total surface area of ~1409 km^2. The BMLC is bounded by a series of islands and sand bars that parallel the coast and divide it into three well–defined regions (Alvarez–Borrego et al. 1975): 1) a northwest zone of canals and mangrove–lined channels (~299 km^2); 2) a central zone, consisting of Bahía Magdalena (~696 km^2); and 3) a southeast zone, composed of Bahía Almejas (~414 km^2).

The northwest region, sometimes referred to as the "Zona de Canales," is bordered by Isla Magdalena to the west and connects to the Pacific from three northern entrances: Boca la Soledad, Boca Santo Domingo, and Boca las Animas (Fig. 1). Although some authors consider this region to terminate at either Boca Santo Domingo or Boca las Animas, for the purposes of this review, the Zona de Canales was considered the entire contiguous inshore area north of Bahía Magdalena. The interior canals and channels that constitute the great majority of this region are narrow (0.2–2 km) and shallow (mean depth 3.5 m; Alvarez–Borrego et al. 1975). Maximum depth (17.8 m) is located in an outer channel to the extreme southwest, near the Bahía Magdalena boundary (~24.81° N, 112.17° W; NIMA, 1998). Because of the physical characteristics of this region and tidal fluctuations, the morphology of the littoral zone is irregular and temporally variable.

Isla Magdalena (to the west) and Isla Santa Margarita (to the south) border Bahía Magdalena, the largest of the three regions (Fig. 3). This embayment is connected to the Pacific Ocean by a pronounced, central channel (Boca Entrada, ~5.5 km wide) that reaches a depth of 38 m. Bahía Magdalena is joined to Bahía Almejas by the deep (maximum depth ~30 m) and relatively narrow (~2.5 km) Canal Gaviota, whereas its

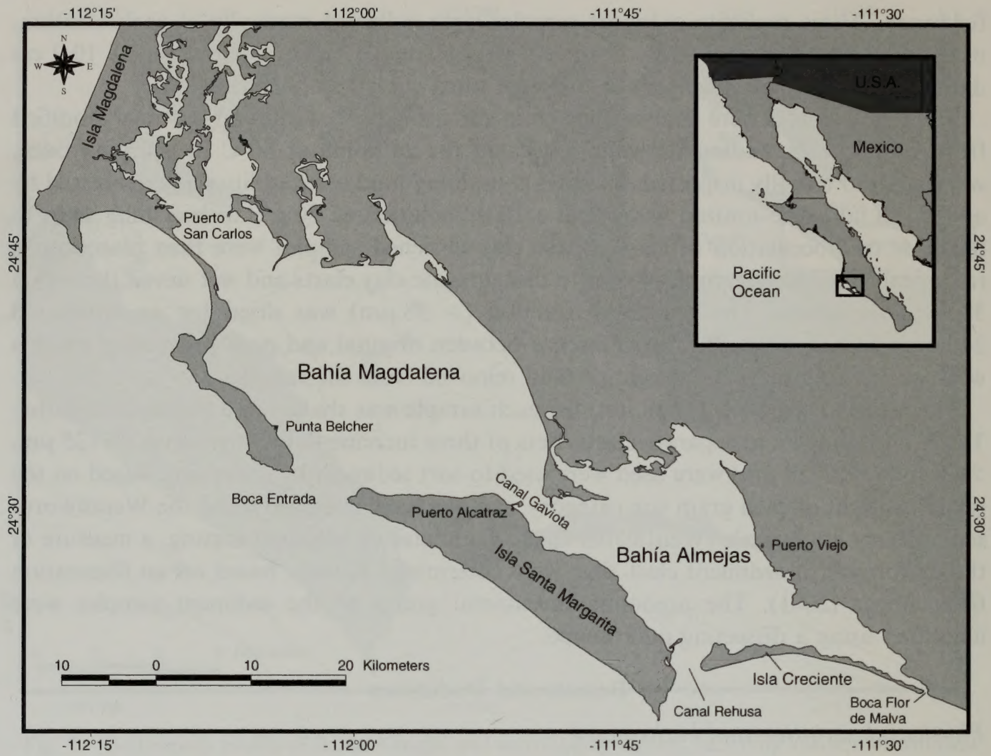

-112°15'
-112°00'
-111°45'
-111°30'
N
W
E
S
Isla Magdalena
Puerto San Carlos
U.S.A.
Mexico
Pacific Ocean
24°45'
Bahía Magdalena
Punta Belcher
Boca Entrada
Puerto Alcatraz
Canal Gaviota
Isla Santa Margarita
Bahía Almejas
Puerto Viejo
24°30'
10 0 10 20 Kilometers
Isla Creciente
Canal Rehusa
Boca Flor de Malva

Fig. 3. Bahía Magdalena and Bahía Almejas, located in the central and southeastern part of the Bahía Magdalena lagoon complex. Primary locations and areas of interest are depicted.

connection to the Zona de Canales is shallower (< 1–12 m) and wider (~4.5 km; Alvarez–Borrego et al. 1975; NIMA 1998). Deep water (> 30 m) is confined to the western region of the lagoon, inshore of Isla Magdalena, with a maximum depth of 44 m located off Punta Belcher (~24.60° N, 112.06° W; NIMA 1998; Fig. 3). Much of Bahía Magdalena, including most of the northern and eastern regions, is < 10 m, with extensive intertidal areas in the extreme northern portions (Alvarez–Borrego et al. 1975; NIMA 1998).

Bahía Almejas is separated from the Pacific Ocean by Isla Santa Margarita, which forms its western border, and Isla Creciente, which forms its southern border (Fig. 3). The shallow, southeastern portion of Bahía Almejas is sometimes referred to as Bahía Santa Marina. Open sea connections from Bahía Almejas are present just east of Isla Creciente through Boca Flor de Malva and west of Isla Creciente through Canal Rehusa. Both conduits are narrow and shallow (0.2–2 km, < 1–14 m) with strong currents, and do not typically permit navigation (Alvarez–Borrego et al. 1975; NIMA 1998; pers. obs.).

The maximum depth of Bahía Almejas is 27.5 m (~24.46–24.47° N, 111.73° W), but most of the region is considerably shallower (NIMA 1998). The deepest portions are located inshore of Isla Santa Margarita, and extend northwest to the Bahía Magdalena boundary (Fig. 2). Depths > 20 m are confined to these regions and constitute only ~6.5% (27 km^2) of the Bay floor area, based on surface area extrapolations. Depths of 10–20 m occur in the central and northwest regions, surrounding the deepest isobaths and in association with Canal Rehusa. Approximately 22.5% (93 km^2) of Bahía Almejas overlies this depth range. The great majority of the lagoon is < 10 m (~71.0%, 294 km^2)

and much of the northern and southeastern regions are exposed at low tides (Alvarez–Borrego et al. 1975; pers. obs.).

Geology and tides

As a result of historic subduction and subsequent transform (NW–SE) faulting along the Pacific coast of the Baja California peninsula, the continental shelf is typically narrow (< 20 km), but widens to 50–70 km in association with most central and southern embayments (Inman and Nordstrom 1971; Spencer and Normark 1989; Ibarra–Obando et al. 2001; Sedlock 2003). Offshore of the BMLC, the continental shelf is narrowest off Bahía Magdalena, with the shelf break (~–200 m) located only ~19 km from Boca Entrada (NIMA 1998). The sea floor of the Pacific Baja continental shelf is composed of heavily faulted volcanic and sedimentary rock that is either exposed or thinly covered with recent (Quaternary) sediment (Lankford 1977; Frizzell 1984). Within the last ~80,000 years, depressions were formed throughout the inshore parts of this region from differential combinations of tectonic, sedimentary, and hydrological processes (Lankford 1977). Rising sea level during the last ~20,000 years filled these depressions and transformed them into modern lagoons and embayments (Lambeck and Chappell 2001).

Based on their patterns of origin, Bahía Magdalena and Bahía Almejas are considered tectonic structural lagoons whereas the Zona de Canales is a Gilbert de Beaumont barrier lagoon (Lankford 1977). Tectonic structural lagoons characteristically consist of depressions and/or barriers produced by faulting, folding, or vulcanism that are independent of sea level history. The typical oval form and irregular bathymetry are consistent, with only slight modifications caused by localized run–off. In contrast, Gilbert de Beaumont barrier lagoons are situated between the mainland coast and bordering sand barriers, and were formed within the last 5,000 years at current sea level. Tidal action, storm surges, and aeolian sands modify the form and bathymetry of these shallow, elongate lagoons. Both Bahía Magdalena and Bahía Almejas were formed by northwest–southeast faulting along the Tosco–Abreojos fault zone, with the upthrown side of the fault zone forming Isla Santa Margarita and Isla Magdalena (Spencer and Normark 1979; Blake et al. 1984). No specific scenario has been proposed for the origin of the Zona de Canales.

The sedimentary composition of the BMLC consists primarily of fine to very fine sand, with appreciable amounts of lime and clay (Félix–Pico et al. 1986; Gutiérrez–Sánchez 1997). Rocky substrate is uncommon and mainly limited to the western margins of Bahía Magdalena and Bahía Almejas where reefs are present off Isla Magdalena and Isla Santa Margarita (pers. obs). Local current patterns are largely responsible for spatial differences in grain size and sorting. Generally, very fine sand is found in the deepest portions of the Bays; fine, very well sorted sand is found at moderate depths; shallow waters at the margins of the Bay mouths are composed of moderately sorted, fine sand; and medium–sized sand is located in the channels, shallow water regions, and at the margins of sand bars. Coarse sand is confined to Canal Gaviota (Félix–Pico et al. 1986). The Zona de Canales is composed of sands, ranging from ~60% medium and coarse sand near Boca Santo Domingo to fine sand in association with weak tidal currents south of Boca la Soledad (Phleger and Ewing 1962). Lime and clay are primarily restricted to Bahía Almejas, where lime is found throughout the central region and clay is also abundant in deep water and off central Isla Santa Margarita (Gutiérrez–Sánchez 1997).

Cores collected in Bahía Almejas support the general sedimentary pattern previously described for this region. Samples located in deep water (> 20 m) were composed of

Table 1. Grain size (mm), classification, sorting, and dominant clast of sediment samples collected in Bahía Almejas during August 1999. Sample collection locations are displayed in Fig. 2.

Sample	Grain size	Classification	Sorting	Dominant clast	Description
1	0.063–0.125	Very fine sand	Very well	60–70% quartz	Quartz arenite sand
2	0.063–0.125	Very fine sand	Very well	60–70% quartz	Quartz arenite sand
3	0.063–0.125	Very fine sand	Very well	60–70% quartz	Quartz arenite sand
4	0.063–0.125	Very fine sand	Very well	60–70% quartz	Quartz arenite sand
5	0.038–0.063	Coarse silt	Moderate	60–70% quartz	Quartz silt w/ shell and organic fragments
6	0.038–0.063	Coarse silt	Moderate	60–70% quartz	Quartz silt w/ shell and organic fragments
7	0.038–0.063	Coarse silt	Moderate	60–70% quartz	Quartz silt w/ shell and organic fragments

moderately sorted coarse silt (38 μm–63 μm) with shell and organic fragments, whereas those at shallow depths (< 10 m) were composed of very well sorted very fine arenite sand (63 μm–125 μm; Table 1). The dominant mineral was quartz (60–70%; Table 1). All samples contained < 10% medium and fine silt (< 38 μm). The presence and contribution of lime and arsenic, which is present in elevated concentrations, especially at the transition between Bahía Magdalena and the Zona de Canales (Shumilin et al. 2005), were not determined.

The tidal regime (24.8 hours) in the BMLC is mixed semidiurnal, with periods of higher high water followed by those of lower low water, a condition that produces greater current velocities during ebb tides (Lankford 1977; Obeso–Nieblas et al. 1999). The tidal range is considerable and varies throughout the region, measuring 1.19 m at Canal Rehusa, 1.46 m at Puerto Alcatraz, and 1.70 m at Puerto San Carlos (Fig. 3; NIMA 1998; Obeso–Nieblas et al. 1999). Tidal currents are an important source of energy for lagoon systems, especially in canals and channels, for erosion and transportation of sediment, and for mixing of waters (Lankford 1977; Guerrero et al. 1988). Greatest current velocities occur during ebb lower low water at the mouth of Bahía Magdalena (1.09 m/s), and are similar at Canal Gaviota (0.52 m/s) and Canal Rehusa (0.50 m/s; Fig. 3; Obeso–Nieblas et al. 1999). These differential greater ebb velocities flush suspended sediment and slow or inhibit the sedimentary infilling process that is typical to most lagoons (Postma 1965; Obeso–Nieblas et al. 1999). Whereas current velocities are considerable in channels and canals, they are slight in the other regions of the BMLC, with nearly quiescent water in the central part of Bahía Almejas (Obeso–Nieblas et al. 1999). The general flow pattern at flood tides results in an influx of water to Bahía Almejas both through the Canal Gaviota and Canal Rehusa, a situation that reverses at ebb tides.

Hydrology and climate

The California Current System (CCS), which represents the eastern limb of the anticyclonic North Pacific gyre, has a pronounced effect on the structure and function of coastal upwelling off the Baja California Peninsula and the climate and hydrology of regional lagoonal systems (Lynn and Simpson 1987; Ibarra–Obando et al. 2001). The CCS consists of the California Current, a surface current (0–300 m deep) that extends to 900 km offshore and transports cool, low salinity, oxygen–rich water towards the North Equatorial Current, and the California Countercurrent (Countercurrent), a northward flowing nearshore (typically within 150 km) current of contrasting characteristics (Lynn and Simpson 1987). In the spring and summer, the Countercurrent is covered by southward flowing surface waters and typically occurs at depths of 200–500 m. In fall and winter, the Countercurrent reaches nearshore surface waters in California where the flow is often poleward (Ibarra–Obando et al. 2001).

Off the Baja California Peninsula, the core of the California Current is especially close to shore (< 200 km) and the Countercurrent is less pronounced. Although there is strong seasonal variability in equatorward flow (maximum speed = 20 cm/s in March, April), poleward flow is very weak or nonexistent in northern and central regions and typically confined to winter months in southern regions (Lynn and Simpson 1987). However, as a result of latitudinal temperature gradients, the mean annual sea surface temperature and variability increase greatly from northern California (12° ± 3.5°C) to offshore of Bahía Magdalena (23° ± 10°C). The impact of El Niño Southern Oscillation (ENSO) events on the CCS include enhanced Countercurrent intensity and width, a dominant cyclonic circulation pattern, reduced upwelling, and intensive warming of the upper mixed layer (Lynn et al. 1995).

The offshore region adjacent to the BMLC is considered a wind–driven upwelling system. Brisk northerly and northwesterly winds, created by the gradient between warm, low–pressure inland regions and cool, high–pressure offshore regions, induce offshore transport of surface waters and drive this system (Bakun and Nelson 1977; Ibarra–Obando et al. 2001). The onset and persistence of these winds are influenced by CCS conditions, with strong equatorial flow evident during periods of upwelling and reduced or poleward flow typically associated with the absence of upwelling. Although the most intense period occurs during spring and early summer (March–June), upwelling persists episodically throughout the year (Bakun and Nelson 1977). Variability in the CCS and the timing and intensity of upwelling greatly influences the physical characteristics (e.g., temperature, salinity, dissolved oxygen) of coastal lagoon systems.

Surface temperature within the BMLC is consistently greater than that of adjacent ocean waters and is spatially and temporally variable. Minimum monthly temperatures (20.3 ± 0.5°C, mean and standard deviation), averaged throughout this region from data collected in 1913, 1974–1975, and 1981–1998, typically occur during January or February. Maximum values are reached in August (26.6 ± 1.2°C) and September (26.9 ± 1.0°C; Lluch–Belda et al. 2000). In general, elevated temperatures are located in the interior portions of the embayments and cooler waters are found near the open sea connections. This situation is most evident in Bahía Magdalena during periods of coastal upwelling, when cool oceanic water is advected into the Bay (Bakun and Nelson 1977; Lluch–Belda et al. 2000). The BMLC is warmer than the adjacent Pacific Ocean during all months of the year, with the smallest differences (< 0.7°C) occurring between October and January and the greatest (2.6–3.7°C) between March and August. During ENSO conditions, temperatures in these embayments can reach > 31°C with anomalies > 6°C (Lluch–Belda et al. 2000).

Bahía Almejas (23.1 ± 2.6°C) and the Zona de Canales (23.1 ± 3.0°C) have similar average annual temperatures but Bahía Magdalena is slightly cooler (22.3 ± 2.5°C), with characteristics that are more oceanic (Lluch–Belda et al. 2000). The highest average monthly temperatures are recorded during August in shallow regions of the Zona de Canales (> 29.0°C) and the lowest during May (< 18.0°C) in west–central Bahía Magdalena, a region of upwelling (Alvarez–Borrego et al. 1975; Lluch–Belda et al. 2000). In Bahía Almejas, temperatures remain consistent (20.3–21.5°C) between December and May, increase slightly during June (22.3°C) and then remain high (> 25.0) from July to

October, peaking in August (27.7°C). November (23.2°C), like June, represents a transition month. This temporal pattern is also evident in the Zona de Canales, but differs in Bahía Magdalena, where the coldest temperatures coincide with upwelling in April and May. Monthly average temperature is highly uniform throughout Bahía Almejas but more variable in the other regions, especially during June and July (Lluch–Belda et al. 2000).

Hydrologic conditions in the BMLC are hypersaline throughout the year as a result of low precipitation, the typical absence of fresh water input, and a high rate of evaporation. The distribution of surface salinity is largely dependent on spatial temperature and depth differences, with values lowest near open sea connections and highest at shallow, interior locations. Dissolved oxygen content, however, is strongly correlated with primary productivity and remains elevated throughout the year (Alvarez–Borrego et al. 1975). The Zona de Canales is the most variable region because of its shallow bathymetry and the differential influence of ocean waters between the northern and southern outlets. In this region, surface salinity increases along a consistent north–south gradient, reaching highs (39.2‰) in July and August and lows (34.1‰) in March. Dissolved oxygen content ranges from 3.9 ml/l during July and August to 5.3 ml/l during March. Percent saturation is consistently high and varies from 83 to 107 (Alvarez–Borrego et al. 1975). In Bahía Magdalena, salinity values are less variable than in the Zona de Canales, ranging from 34.0–36.0‰ with consistently lower values measured in the western part of the Bay. Dissolved oxygen content is typically > 5.0 ml/l (> 100% saturated) but ranges from lows of 2.74 ml/l (~60% saturated) during June in northwest nearshore waters, to highs of > 6.0 ml/l (~120% saturated) during July and August in west–central nearshore waters (Alvarez–Borrego et al. 1975). In Bahía Almejas, surface salinity values are relatively uniform throughout the year, ranging from lows of 34.0‰ in the west–central region, to highs of 35.1‰ in the northeast. Dissolved oxygen content is typically 5.0 ml/l or greater (> 100% saturated) with little spatial or temporal variation (Alvarez–Borrego et al. 1975). Both maximum (8.5) and minimum (7.4) pH values for the BMLC were recorded in the Zona de Canales during June and October, respectively. The pH of both Magdalena and Bahía Almejas is less variable, ranging from 8.0–8.5 (Alvarez–Borrego et al. 1975).

The BMLC region is part of the Sonoran Desert, and the climate characteristically varies from temperate to hot and is very dry (Garcia 1973; MacMahon 1997). Mean annual air temperature is ~22°C, and ranges from 12° in December and January to 30° in July and August (Garcia 1973; National Climatic Data Center 1994). Precipitation in this region falls irregularly during two consecutive rainy periods, from July to October and November to February, but is mainly restricted to summer and early fall (Lankford 1977; Salinas–Zavala et al. 1990). During this time, tropical storms typically originating in the Gulf of Tehuantepec may reach the BMLC (Lankford 1977). The average annual rainfall in BCS is 160 mm, although interannual values may differ substantially (from 46–608 mm) as a result of the variable intensity of summer storm seasons (Ibarra–Obando et al. 2001). Annual precipitation values of 1–14 mm have been reported for the northern BMLC (Alvarez–Borrego et al. 1975), but these amounts probably actually represent centimeters. There is no permanent river input in the BMLC, but rather periodic inputs during infrequent rainy periods. Run–off in this region is therefore negligible (Guerrero et al. 1988; pers. obs).

Regional marine biogeography

The west coast of North America has been divided into biogeographic regions, or faunal provinces, by many authors, often differing somewhat in terminology and boundaries. Most of these authors, however, consider the BMLC to represent a transition zone between warm–temperate and tropical species (e.g., Hubbs 1960; Briggs 1974; Brusca 1980; Allen and Robertston 1994). According to a modified version of Briggs' (1974) classification system, the BMLC is situated at the boundary between the San Diego Province of the temperate California Region and the Cortez Province of the tropical East Pacific Region (Hastings 2000). The San Diego Province, also referred to as the California Province (McLean 1969; Brusca 1980), ranges north to Point Conception, California (34° 10′ N). The Cortez Province extends around the southern tip of Baja California Sur, and continues through the Gulf of California to Topolobampo (25° 36′ N; Hastings 2000). Some authors consider the Cortez Province to be incorporated within larger Mexican (to the Gulf of Tehuantepec) or Panamic Provinces (to Peru; Hubbs 1960; Brusca 1980; Aguilar–Palomino et al. 2001).

The faunal break between the San Diego and Cortez Provinces is neither abrupt nor consistent as a result of spatial and temporal discontinuities in water temperature and current regimes (Hubbs 1948, 1960; Hewitt 1981; McLain and Thomas 1983). Many tropical species extend north of the BMLC for a considerable distance, inhabiting shallow, protected bays and inlets, whereas warm–temperate species are found in nearshore coastal regions and cool–temperate species are associated with upwelling areas (Garth 1960; Hubbs 1960). Upwelling regions and associated cold–temperate fauna typically reach their terminus offshore of the BMLC and warm–temperate species decline abruptly south of this region (Hubbs 1960; Aguilar–Palomino et al. 2001, Ibarra–Obando et al. 2001). In contrast, Punta Eugenia (27° 50′ N) is considered the northern limit of many tropical taxa, including fishes (Hubbs 1960; Hastings, 2000), crabs (Garth 1960), bryozoans (Soule 1960), and molluscs (Hall 1964; Valentine 1966). Based on these factors, the entire region between the BMLC and Punta Eugenia can be considered a transitional zone of discontinuous overlap between temperate (San Diego) and tropical (Cortez) fauna (Brusca 1980).

Littoral vegetation and marine algae

Along the Pacific coast of BCS, between ~27° N and ~24° N, mangroves replace salt marsh species (e.g., *Spartina foliosa*, *Sarcocornia pacifica*) as the dominant littoral vegetation (Ibarra–Obando et al. 2001). White (*Laguncularia racemosa*), red (*Rhizophora mangle*), and black (*Avicennia germinans*) mangrove species are present throughout the BMLC (Nienhuis and Guerrero–Caballero 1985; Gárate–Lizárraga and Siqueiros–Beltrones 1998; pers. obs.). In Bahía Magdalena and Bahía Almejas, these species occur in isolated littoral forests in contrast to the more abundant, but smaller morphs that line the canals to the northwest (Gárate–Lizárraga and Siqueiros–Beltrones 1998). Mangroves provide habitat for a great variety of invertebrates and fishes in the BMLC that either use their roots for shelter, or inhabit inlets that are fringed by this vegetation (pers. obs.).

More than 130 species of macroalgae have been recorded from the BMLC (Sánchez–Rodríguez et al. 1989). In general, as latitude decreases along the Pacific coast of the Baja California peninsula, tropical and subtropical red algae (Rhodophyta) become abundant (Ibarra–Obando et al. 2001). This group is locally dominant, with 88 species and 18 families representing an estimated 66.6% of total macroalgal biomass (Sánchez–Rodríguez et al. 1989). The families Corallinaceae (N = 20), Rhodomelaceae (N = 16), and Ceramiaceae (N = 14) are most speciose (Sánchez–Rodríguez et al. 1989). In contrast to Rhodophyta, brown algae (Phaeophyta) declines in abundance and species richness as latitude along the Pacific coast of the Baja peninsula decreases (Aguilar–Rosas and Aguilar–Rosas 1993). Twenty–two species and six families of Phaeophyta are known from the BMLC, contributing a measured 16.7% to total macroalgal biomass. Among brown algas, the family Dictyotaceae (N = 11) is most speciose (Sánchez–Rodríguez et al. 1989). Green algae (Chlorophyta) constitutes an estimated 16.7% of macroalgal biomass in the BMLC, with seven families and 22 species (Sánchez–Rodríguez et al. 1989). Most Chlorophyta species belong to the families Ulvaceae (N = 7) and Codiaceae (N = 6; Sánchez–Rodríguez et al. 1989). Eelgrass (Chlorophyta: *Z. marina*), the most abundant subtidal macrophyte in coastal lagoons of the Baja California peninsula, reaches its southern limit but exhibits its highest regional flowering effort at the BMLC (Riosmena–Rodríguez and Sánchez–Lizaso 1996; Santamaría–Gallegos et al. 2003). The BMLC also represents the southernmost occurrence of surfgrass (*P. torreyi*; Riosmena–Rodríguez and Sánchez–Lizaso 1996).

Phytoplankton

The BMLC is a region of high primary productivity throughout the year, with maximum reported microphytoplankton densities of 1,500,000 cells/liter and maximum reported nanoplankton densities of 791,760 cells/liter (Alvarez–Borrego et al. 1975; Nienhuis and Guerrero–Caballero 1985; Gárate–Lizárraga et al. 2001). There are two general patterns in phytoplankton abundance, a period of high densities from November to May, corresponding to a cool–water period, and a period of relatively low densities from June to October, corresponding to a warm–water period (Nienhuis and Guerrero–Caballero 1985; Gárate–Lizárraga et al. 2001). Phytoplankton abundance is similar in surface and subsurface waters (Gárate–Lizárraga et al. 2001). Bahía Magdalena is the most productive of the three BMLC regions, primarily because of the advection of upwelled oceanic water. Especially between March and June, advection infuses the west–central region of Bahía Magdalena with nutrients during flood tides, resulting in increased photosynthetic activity and the export of elevated levels of dissolved oxygen and chlorophyll *a* to adjacent oceanic waters during ebb tides (Alvarez–Borrego et al. 1975; Acosta–Ruiz and Lara–Lara 1978; Guerrero et al. 1988).

The structure and abundance of the local phytoplankton assemblage are extremely variable both temporally and spatially, and are determined by a complex interaction of hydrological factors (Gárate–Lizárraga et al. 2001). The presence of nutrient–rich water pockets, either as a result of upwelling, mineralization of allochthonous inputs from mangroves (especially in eastern and north–western Bahía Magdalena), or tidal mixing are some of the primary factors that determine distribution and density of phytoplankton (Nienhuis and Guerrero–Caballero 1985; Gárate–Lizárraga and Siqueiros–Beltrones 1998). According to studies conducted by Nienhuis and Guerrero–Caballero (1985) during 1980 and 1981 and Gárate–Lizárraga and Siqueiros–Beltrones (1998) during 1982–1986, microphytoplankton is the dominant phytoplankton component with nanoplankton representing a minor fraction, except during warmest water periods. Similar to previous studies, Gárate–Lizárraga et al. (2001) reported maximum abundance and microphytoplankton diversity during 1988–1989 at the end of the cool season (May) and relatively low mean values in concurrence with warm periods. However, Gárate–Lizárraga et al. (2001) determined that nanoplankton (primarily phytoflagellates, coccolithophorids, and naviculoid diatoms) contributed most to total phytoplankton abundance and was especially dominant in winter months. These inconsistent results are probably a consequence of the extremely high temporal and spatial variability in BMLC hydrological parameters. Therefore, there is not likely a predictably characteristic phytoplankton assemblage, but rather a dynamic mosaic of available flora.

At least 87 genera and 277 taxa of phytoplankton have been reported from the BMLC (Gárate–Lizárraga and Sisqueiros–Beltrones 1998; Gárate–Lizárraga and Verdugo–Díaz 2001). Within the microphytoplankton, diatoms [especially *Chaetoceros* spp. (N = 27), *Rhizosolenia* spp. (N = 15), and *Coscinodiscus* spp. (N = 9)] are the dominant species, whereas, nanoplankton is primarily composed of Chrysophyceae and Cryptophyceae (Nienhuis and Guerrero–Caballero 1985; Gárate–Lizárraga and Siqueiros–Beltrones 1998). The species composition and diversity of the phytoplankton assemblage vary throughout the year in accordance with changing hydrological conditions (Nienhuis and Guerrero–Caballero 1985; Gárate–Lizárraga and Siqueiros–Beltrones 1998). Diatoms are the most diverse (N = 171) and abundant taxa, followed by dinoflagellates (N = 84), silicoflagellates (N = 5), and cyanobacteria (N = 5; Gárate–Lizárraga 1992). Between 22–27 diatom species that are widely distributed along the coastal Baja California peninsula are responsible for most of the phytoplankton dynamics. Phytoplankton diversity is greatest in association with the oceanic region of Bahía Magdalena and lowest in association with episodic, widespread blooms of different species throughout the year (Gárate–Lizárraga and Sisqueiros–Beltrones 1998). Diatoms generally increase in abundance during periods of warm–water, whereas dinoflaggelates are typically more abundant in association with cooler water (Gárate–Lizárraga and Siqueiros–Beltrones 1998; Ibarra–Obando et al. 2001), although Gárate–Lizárraga et al. (2001) reported an opposite pattern. El Niño Southern Oscillation warming causes diminished species richness, diversity, and abundance of phytoplankton in this region, the effects of which may linger for one or more years (Nienhuis and Guerrero–Caballero 1986; Gárate–Lizárraga and Siqueiros–Beltrones 1998).

Zooplankton

The BMLC zooplankton assemblage is dominated by copepods, which comprise 50–90% of total zooplankton biomass throughout the year (Palomares–García 1992; Palomares–García and Gómez–Gutiérrez 1996). At least 79 species and 35 genera have been reported, with calanoids (*Acartia lilljeborgii*, *A. clausi*, and *Paracalanus parvus*) typically representing > 75% of total copepod biomass (Palomares–García 1992; Palomares–García and Gómez–Gutiérrez 1996). This situation is characteristic of other coastal lagoons, where one or few species are numerically dominant, and in contrast to the condition in adjacent coastal waters where a more diverse and less abundant assemblage is common (Margalef 1969). Cyclopoid copepods (i.e., *Corycaeus* spp. and *Oithona* spp.) are present in relatively low to moderate numbers throughout the year. Only one species of harpacticoid copepod, *Euterpina acutifrons*, is common to the BMLC (Palomares–García 1992). Although copepods dominate zooplankton biomass, they do not influence total plankton abundance, because phytoplankton biomass is considerably greater throughout the year.

There is a well–defined seasonal pattern of copepod diversity and species succession in the BMLC that is closely related to changes in hydrology, especially the direction and intensity of the California Current. The copepod assemblage is less diverse during cool–water periods (winter and spring), when strong southward flow is dominant and the fauna is largely restricted to temperate species. During warm–water periods (summer and fall), when southward flow is weak or reversed, tropical species also become prevalent and diversity increases (Palomares–García 1992; Palomares–García and Gómez–

Gutiérrez 1996; Palomares–García et al. 2003). Locally, the greatest diversity is typically associated with the assemblage at the mouths of Bahía Magdalena and Bahía Almejas, where neritic (e.g., *P. parvus*, *Calanus pacificus*) and oceanic species predominate, especially during periods of upwelling. Minimum diversity values correspond to high densities of *Acartia* spp. (Palomares–García 1992; Palomares–García and Gómez–Gutiérrez 1996). This is especially evident of the typical summer condition in Bahía Almejas, where *A. lilljeborgii* is overwhelmingly dominant (Palomares–García 1992). Generally, resident species such as *Acartia* spp. are rarely or never found outside the BMLC, exhibit the strongest seasonal variations, and comprise 50–85% of copepod abundance (Palomares–García 1992; Palomares–García and Gómez–Gutiérrez 1996). The seasonal succession of the copepod assemblage, most evident in the replacement of *P. parvus* during cool–water periods by *A. lilljeborgii* during warm–water periods, is predictable and stable.

This pattern of copepod succession remains consistent even under ENSO conditions, although the relative abundance of tropical species increases and the tropically distributed *A. tonsa* may replace the more temperate *A. clausi* (Palomares–García and Gómez–Gutiérrez 1996; Palomares–García et al. 2003). These characteristics are in stark contrast to those of the phytoplankton assemblage, which is highly variable both intra– and interannually (Nienhuis and Guerrero–Caballero 1986; Gárate–Lizárraga 1992). The permanence of a defined seasonal pattern of relative abundance suggests that the BMLC copepod assemblage is rather stable and that the dominant taxa are highly adaptable to changing environmental conditions.

Chaetognaths are also common components of the BMLC zooplankton assemblage. Of 10 *Sagitta* species reported from the BMLC, *S. euneritica* is the most abundant throughout the year, numerically comprising between 82% (fall and winter) and 95% (spring and summer) of all chaetognaths (Cota–Meza et al. 1992). S*agitta enflata* is the next most abundant species, followed by *S. minima*, which is primarily observed in association with upwelled water at the mouth of Bahía Magdalena from January to July. A tropical assemblage is typically present in relatively small numbers (3.6%) during the fall (Cota–Meza et al. 1992). Greatest overall densities are reported from Bahía Almejas during winter (6024/10 m^2), spring (1811/10 m^2), and summer (2469/10 m^2), and from Bahía Magdalena during fall (7334/10 m^2; Cota–Meza et al. 1992). The Zona de Canales exhibits the lowest abundance in all seasons.

Immature crabs are also consistent seasonal components of the BMLC zooplankton assemblage. Pelagic red crabs (*Pleuroncodes planipes*) use tidal currents to move between the outer coast and the BMLC, vertically migrating to facilitate advection (Robinson and Gomez–Aguirre 2004). Annual mass strandings of this anomuran species are commonly observed on eastern shores of Isla Magdalena and Isla Santa Margarita between April and June. During this time, primarily juvenile *P. planipes* are advected into Bahía Magdalena with upwelled water and sometimes stranded during ebb tide by peripheral currents, which carry them into the surf zone instead of flushing them from the Bay (Aurioles–Gamboa et al. 1994). Zoea of the dominant local blue crab (*Callinectes bellicosus*) are most abundant in the BMLC during August, when the vast numerical majority (89%) have been observed (Sánchez–Ortiz and Gómez–Gutiérrez 1992). During this time, gravid females migrate from shallow water regions to deeper waters near the mouths of Bahía Magdalena and Bahía Almejas, where larvae are hatched and carried out of the Bays during ebb tides. Juveniles later recruit back to the BMLC at the culmination of their pelagic phase (Sánchez–Ortiz and Gómez–Gutiérrez 1992).

Ichthyoplankton

The ichthyoplankton assemblage in the BMLC has been studied both temporally and spatially with somewhat inconsistent results. Based on samples collected throughout the BMLC in October, March, June, and July/August of 1973–1974, Castro–Barrera (1975) identified larvae of 32 teleost families with Gobiidae and, to a far lesser extent Engraulidae, present in greatest abundance. In addition, clinids, serranids, sciaenids, pomadasyids, and pleuronectiformes were noted at lower abundance. Studies conducted in the same regions during January, February, May, and September of 1989, however, identified larvae belonging to 24 families with Gobiidae (especially *Gillichthys y–cauda*) as the dominant taxa numerically (62.4%) followed by Gerreidae (15.6%) and Clupeidae (especially *Sardinops sagax*, 10.5%). In addition, haemulids (2.2%), blenniids (2.2%), and pleuronectiforms (2.1%) were present in lower abundance (Funes–Rodríguez et al. 1998). These rather incongruous findings are likely because of: 1) different oceanographic conditions present during these studies resulting in a variable spawning assemblage and differential spawning periodicity; and/or 2) temporal changes in the local ichthyofaunal assemblage. However, some patterns are evident. In the inner portions of the BMLC, larvae of resident taxa (e.g., Blenniidae, Gobiidae, Gerreidae, Pleuronectiformes) occur throughout the year in association with relatively high temperatures and zooplankton biomasses. At the mouth of Bahía Magdalena, larval engraulids and clupeids are present in association with lower temperatures and zooplankton biomasses. Temporal characteristics of these groups are inconsistent between studies and therefore not reported (Castro–Barrera 1975; Funes–Rodríguez et al. 1998).

Benthic invertebrates

The marine invertebrate assemblage of the BMLC consists primarily of a tropically derived fauna (Garth 1960; Brusca 1980). However, because this region is a transition zone for many taxa, local species richness and diversity are quite substantial and temperate forms, though relatively rare, are not uncommon (Bertsch 1993; Emilia–González 1993; Hendrickx 1993). This situation is well exemplified by the local brachyuran crab fauna. Of 24 spider crabs (Majidae, Parthenopidae) and 10 cancrid crabs (Portunidae, Cancridae, Xanthidae) noted in Bahía Magdalena and Bahía Almejas, only eight species range farther north than San Ignacio Lagoon (Garth 1960). For grapsid crabs (Grapsidae, Ocypodidae), Bahía Magdalena represents the northern extent of two mangrove associated species (*Goniopsis pulchra*, *Sesarma magdalenense*) and Bahía Almejas the southern extent of the fiddler crab, *Uca crenulata* (Garth 1960). It is noteworthy that the most northerly occurrence of these tropical and subtropical species is in this protected lagoon complex, which is sheltered from the Pacific and contains elevated temperatures. In most cases the nearest unprotected coastal regions harboring these species are more than 500 km to the south (Garth 1960).

Although no complete inventory of the invertebrate fauna exists, the sublittoral benthic macroinvertebrate assemblage of the BMLC has been described. Based on comprehensive spatial and temporal sampling throughout the BMLC, at least 75 species, 50 families, and 64 genera are present (Félix–Pico and García–Domínguez 1993). The taxonomic classification of the 68 most common invertebrate species is as follows: Mollusca (N = 27), Arthropoda (N = 22), Echinodermata (N = 6), Porifera (N = 5), Annelida (N = 4), and Cnidaria (N = 4). The assemblage is dominated by the following species, listed in decreasing order: *C. bellicosus* (crustacean), *Luidia phragma* (echinoderm), *Ascidia interrupta* (ascidian), *Penaeus californiensis* (crustacean), *Sicyonia penicillata* (crustacean), *Loliopsis diomedae* (mollusc), *Obelia plicata* (cnidarian), *Astropecten armatus* (echinoderm), and *Argopecten circularis* (mollusc; Félix–Pico and García–Domínguez 1993). Although all of these species are present throughout the year, many exhibit patterns of seasonal abundance. For instance, *C. bellicosus* numerically constituted 81% of all specimens collected between May and September but only 19% of all individuals between October and February (Sánchez–Ortiz and Gómez–Gutiérrez 1992; Félix–Pico and García–Domínguez 1993). Overall invertebrate abundance is also lower from October to February, possibly because a lower temperature regime is not optimal for the predominantly tropical fauna or because the coinciding loss of perennial algas reduces the amount of available habitat. Spatial heterogeneity was observed within the BMLC invertebrate assemblage, with four distinct species groupings present and well–defined northern (Curva del Diablo, ~24.97°N, −112.15°W) and southern (Puerto Cortés, ~24.48°N, −111.82°W) species extents (Félix–Pico and García–Domínguez 1993). Because sampling was conducted with an epibenthic sled over predominantly soft substrates, several common, commercially important infaunal (e.g., *Crassostrea palmula*, *C. columbiensis*, *C. gigas*) and rock associated (e.g., *H. corrugata*, *H. fulgens*, *P. interruptus*, *P. inflatus*) species were either absent or under–represented in these studies (pers. obs.). Therefore the described assemblage should be considered to represent the dominant macroepibenthic species associated with soft substrates.

Ichthyofauna

Because it is located at a transition zone and includes several habitat types, the BMLC contains a highly diverse ichthyofauna with 315 documented species, corresponding to 92 families and 199 genera (Torres–Orozco and Castro–Aguirre 1992; Castro–Aguirre and Torres–Orozco 1993; Cruz–Agüero et al. 1994; Gutiérrez–Sánchez 1997; Mariano–Meléndez and Villavicencio–Garayzar 1998; Galván–Magaña et al. 2000; Bizzarro, 2005). Of these, 269 species, 171 genera, and 75 families are teleosts. The most speciose families are: Haemulidae (N = 19), Serranidae (N = 17), Sciaenidae (N = 17), and Carangidae (N = 16) (Torres–Orozco and Castro–Aguirre 1992; Galván–Magaña et al. 2000). The faunal assemblage of the BMLC is rather unique when compared with other BCS embayments, but more closely aligned with those of the inner coast (i.e., Bahía de la Paz, Bahía Concepción) than the outer coast (i.e., Laguna San Ignacio, Laguna Ojo de Liebre; Galván–Magana et al. 2000). Among BCS lagoons, only the larger, deeper Bahía de la Paz (N = 384) has greater species richness (Galván–Magana et al. 2000).

Most fishes are tropical and subtropical in origin, but many temperate species are also present (Castro–Aguirre and Torres–Orozco 1993; Gutiérrez–Sánchez 1997; Galván–Magana et al. 2000). The temperate component is not restricted to warm–temperate species of the San Diego province and instead contains a mixture of species with distributions throughout the eastern North Pacific (e.g., Love et al. 2005). These species were likely transported through dispersion via the California Current system, especially during the Wisconsin (early Pleistocene) and earlier ice ages when current patterns and temperate regimes created conditions that favored their establishment (Hubbs 1960; Dawson 1992; Castro–Aguirre and Torres–Orozco 1993). Periods of strong California Current flow and local upwelling continue to seasonally infuse the BMLC with temperate species. Tropical and subtropical elements of the BMLC ichthyofauna are believed to be derived from one of two sources: 1) from remnant populations established as the Baja California Peninsula rifted from the Jalisco region of southwestern Mexico during the Miocene and Pliocene (~4–8 million years ago) and, 2) from the southern Gulf of

California via a Tertiary paleochannel between the BMLC and Bahía La Paz (Castro–Aguirre and Torres–Orozco 1993; Sedlock 2003). Allochthonous fauna are also transported to this region during periods of intense California Countercurrent or North Equatorial Current flow, especially in associated with ENSO conditions (Torres–Orozco and Castro–Aguirre 1992). A very minor component of the tropical ichthyofauna is derived from long distance dispersal, particularly of larval forms, from the Indo–Pacific (Hubbs 1960; Allen and Robertson 1994; Galván–Magaña et al. 2000).

In addition to its great diversity and species richness, the ichthyofauna of the BMLC is temporally variable. Temperature is considered the primary factor affecting the distribution of marine fishes along the Pacific coast of North America and is the main determinant of fish distribution in this region (Hubbs 1948, 1960; Torres–Orozco and Castro–Aguirre 1992; Castro–Aguirre and Torres Orozco 1993). Because the BMLC is located at a faunal boundary, vicissitudes in the CCS greatly affect the species composition and relative abundance of the local ichthyofauna, with temperate species becoming more pronounced in times of strong California Current flow or upwelling and less common during strong Countercurrent flow or during ENSO warming events (Torres–Orozco and Castro–Aguirre 1992; Castro–Aguirre and Torres Orozco 1993; Gutiérrez–Sánchez 1997). The temporally divergent occupation of west–central Bahía Magdalena by the pelagic species *S. sagax* and *Opisthonema libertate* provides a good example of this condition. *Opisthonema libertate* immigrates into Bahía Magdalena as temperatures increase during August, reaches its highest relative abundance from November to January, and then decreases in association with the advection of cooler, upwelled water into the region. In contrast, the more temperately distributed *S. sagax* immigrates into Bahía Magdalena in February and is dominant from April to September, when warmer waters drive it from the region (Casas–Valdez 1987).

Although many species are transient, differential temporal utilization of space enables the persistence of both temperate and tropical residents within the BMLC. Based on monthly trawl surveys of soft bottom regions, Gutiérrez–Sánchez (1997) found fishes of temperate, tropical, and widespread distributions to be among the dominant species numerically (*Etropus crossotus*, *Paralabrax maculatofasciatus*, *Eucinostomus dowii*, *Urobatis maculatus*, and *Ariopsis platypogon*) and by biomass (*P. maculatofasciatus*, *Sphoeroides annulatus*, *Urobatis halleri*, *U. maculatus*, and *E. dowii*). Most temperate species, such as *Paralichthys californicus* and *Pleuronichthys ritteri*, are permanently associated with relatively cool, deeper water regions near Boca Entrada, which remains between 14°C and 18°C even during summer and fall months (Gutiérrez–Sánchez 1997). In winter and spring, tropical species such as *E. dowii*, *Eucinostomus gracilis*, and *A. platypogon* are restricted to the interior regions of the BMLC, where bottom temperatures remain relatively high (15°C to 23°C). During warm–water periods, tropical species increase their distribution and utilize a greater portion of the BMLC. More thermally tolerant species, such as *P. maculatofasciatus*, are widely distributed throughout the year (Gutiérrez–Sánchez 1997). Species richness is greatest between February and July in Bahía Magdalena, when the distinction between cool and warm regions is most pronounced, thereby facilitating the presence of both temperate and tropical species.

Fisheries

Invertebrate fisheries in the BMLC are primarily artisanal and several taxa are harvested. Principal fishery targets include: bivalves (e.g., *Argopecten circularis*, *Crassostrea* spp., *Megapitaria aurantiaca*), crabs (e.g., *C. bellicosus*), lobsters (e.g., *P. interruptus*, *P. inflatus*), shrimps (e.g., *P. californiensis*, *Panaeus stylirostris*), abalones (e.g., *H. fulgens*, *H. corrugata*), and snails (e.g., *Astrea undosa*, *Astrea turbanica*; Flores–Castanon 1980; Ramírez–Rodríguez 1987; Sánchez–Ortiz and Gómez–Gutiérrez 1992; Casas–Valdez et al. 1996; pers. obs.). Mariculture of bivalves (e.g., *Argopecten venticosus*, *Crassostrea gigas*, *Nodipecten subnodosus*) throughout the BMLC and shrimp (e.g., *P. stylirostris*) in southeastern Bahía Almejas is also common (Casillas et al. 1988; Cáceres–Martínez and García–Bustamante 1990; Maeda–Martínez et al. 2000, Koch et al. 2005).

Both pelagic and demersal fishes are targeted in the BMLC. Schooling pelagic fishes such as sardine (*S. sagax*), herrings (*O. libertate*, *Etrumeus teres*), anchovy (*Cetengraulis mysticetus*), and Pacific mackerel (*Scomber japonicus*) support large industrial fisheries (Casas–Valdez 1987; Félix–Uraga et al. 1996; Robinson et al. 2000; Morales–Bojórquez 2002). Artisanal fishermen target demersal teleosts and elasmobranchs (Gutiérrez–Uribe 1987; Ramírez–Rodríguez 1987; Villavicencio–Garayzar 1995). Although no additional studies have been recently published, earlier works indicated that serranids (e.g., *Epinephelus analogus*, *Paralabrax nebulifer*, *Mycteroperca* spp.) were the primary teleost targets, with malacanthids (e.g., *Caulolatilus princeps*), gerreids (e.g., *Eucinostomus argenteus*, *Diapterus peruvianus*), haemulids (e.g., *Haemulon scudderi*, *Pomadasys* spp.), sciaenids (e.g., *Cynoscion parvipinnis*, *Bairdiella icistia*), mugilids (e.g., *Mugil cephalus*, *M. curema*), carangids (e.g., *Trachinotus kennedyi*), lutjanids (e.g., *Lutjanus argentiventris*), and scombrids (e.g., *Scomberomorus sierra*) also taken (Gutiérrez–Uribe 1987; Ramírez–Rodríguez 1987). Information concerning the BMLC artisanal elasmobranch fishery is largely restricted to studies conducted at a single encampment (Puerto Viejo, Fig. 3) in Bahía Almejas at which *Rhinobatos productus* and *Dasyatis dipeterura* were reported as primary targets (Villavicencio–Garayzar 1995; Salazar–Hermoso and Villavicencio–Garayzar 1999; Bizzarro 2005).

Although the natural resources of the BMLC have been exploited for almost a century, resident populations have not greatly expanded and settlements consist primarily of artisanal fishing villages. The two largest towns, Puerto San Carlos (Bahía Magdalena) and Puerto Adolfo Lopez Mateos (Zona de Canales), contain less than 5,000 combined residents (INEGI 2000). However, the BMLC has received a considerable influx of transient fishermen since 1970 (Young 2001), and almost all current settlements were established and used for fishing activities. Several local fishery stocks, including abalone (*Haliotis* spp.), spiny lobster (*Panulirus* spp.), and large demersal teleosts (e.g., serranids) appear to have suffered population declines, largely as a result of unregulated and illegal exploitation (Young 2001). In addition, Puerto Viejo is now abandoned after the apparent serial depletion of large sharks (e.g., *Carcharhinus* spp.) and subsequently rays (e.g., *Rhinobatos productus*; Bizzarro 2005).

Conclusions and Recommendations

The Bahía Magdalena lagoon complex (BMLC) is an important hydrological, biological, and socio–economic center. It is one of the most biologically diverse regions in the coastal Mexican Pacific and is a nursery area for a great variety of invertebrate and vertebrate species, several of which support local fisheries. Because of the documented biological and socio–economic significance of the BMLC and recent declines in several commercially fished species, it is recommended that local fisheries are better monitored and regulated. It is also suggested that increased scientific attention, especially in the form of multi–disciplinary studies detailing community structure, stability, and trophic relationships be focused on the BMLC. This type of research is especially important because potential increases in water temperatures as a result of global climate change may modify this region from a transitional zone of temperate and tropical species to one dominated by tropical biota. A loss or reduction in the occurrence of temperate biota will likely result in decreased diversity and may adversely affect fisheries productivity and nursery function of some species.

Acknowledgments

I thank Joan Parker and the Moss Landing Marine Laboratories library staff for acquiring much of the source material used in this review. Thanks also to Patrick Mitts for grain size analysis. Gregor Cailliet, Lara Ferry–Graham, Ralph Larson, and Stori Oates edited this manuscript and provided helpful comments and suggestions.

Literature Cited

Acosta–Ruíz, M. and J.R. Lara–Lara. 1978. Resultados fisicoquímicos en un estudio de variación diurnal en el area central de Bahía Magdalena, B.C.S. Cienc. Mar., 5(1): 37–46.

Aguilar–Palomino, B., C. Pérez–Reyes, F. Galván–Magaña, and A. Abitía–Cardenas. 2001. Ictiofauna de la Bahía Navidad, Jalisco, México. Rev. Biol. Trop., 49(1): 173–190.

Aguilar–Rosas, L.E. and R. Aguilar–Rosas. 1993. Ficogeografía de las algas pardas (Phaeophyta) de la Península de Baja California. Pp. 197–206 *in* Biodiversidad marina y costera de México. (Salazar–Vallejo, S.I. and N.E. González, eds.) Com. Nal. Biodiversidad–Centro Investig, Quintana Roo, Mexico.

Allen, G.R. and D.R. Robertson. 1994. Fishes of the tropical eastern Pacific. University of Hawaii Press, Honolulu, HI. 332 pp.

Alvarez–Borrego, B.S., A. Galindo–Bect, and A. Chee–Barragán. 1975. Características hidroquímicas de Bahía Magdalena, B.C.S. Cienc. Mar., 2(2): 94–110.

Aurioles–Gamboa, D., M.I. Castro–González, and R. Pérez–Flores. 1994. Annual mass strandings of pelagic red crabs, *Pleuroncodes planipes* (Crustacea: Anomura: Galatheidae), in Bahía Magdalena, Baja California Sur, Mexico. Fish. Bull., 92:464–470.

Bakun, A. and C.S. Nelson. 1977. Climatology of upwelling related processes off Baja California. CalCOFI, 19:107–127.

Bartsch, P. and H.H. Rehde. 1939. Mollusks collected on the presidential cruise of 1938. Smith. Misc. Coll., 98(10): 1–18.

Beebe, W. and J. Tee–Van. 1941a. Eastern Pacific expeditions of the New York Zoological Society. XXV. Fishes from the tropical eastern Pacific (from Cedros Island, Lower California, South to the Galapagos Island and Northern Peru). Part 2. Sharks. Zoologica, 26:93–124.

——— and ———. 1941b. Eastern Pacific expeditions of the New York Zoological Society. XXVIII. Fishes from the tropical eastern Pacific (from Cedros Island, Lower California, South to the Galapagos Island and Northern Peru). Part 3. Rays, mantas, and chimaeras. Zoologica, 26: 245–280.

Bertsch, H. 1993. Opsitobranquios (Mollusca) de la costa occidental de México. Pp. 253–270 *in* Biodiversidad marina y costera de México. (Salazar–Vallejo, S.I. and N.E. González, eds.) Com. Nal. Biodiversidad–Centro Investig, Quintana Roo, Mexico.

Bizzarro, J.J. 2005. Fishery biology and feeding ecology of rays in Bahía Almejas, Mexico. M.S. Thesis. Moss Landing Marine Laboratories/California State University, San Francisco. 468 pp.

———, W.D. Smith, J.F. Márquez–Farías, and R.E. Hueter. 2007. Artisanal fisheries and reproductive biology of the golden cownose ray, *Rhinoptera steindachneri* Evermann and Jenkins 1891, in the northern Mexican Pacific. Fish. Res., 84(2): 137–146.

Blake, M.C. Jr., A.S. Javko, and T.E. Moore. 1984. Tectonostratigraphic terranes of Magdalena Island, Baja California Sur. Pp. 183–191 *in* Geology of the Baja California Peninsula. (Frizzell, V.A., ed.), Soc. Econ. Paleontol. Mineral. Pac. Sec. 39.

Boggs, S.A. Jr. 2001. Principles of stratigraphy and sedimentology. Prentice Hall, Upper Saddle River, NJ. 726 pp.

Briggs, J.C. 1974. Marine Zoogeography. McGraw–Hill, New York, NY. 475 pp.

Brusca, R.C. 1980. Common intertidal invertebrates of the Gulf of California. The University of Arizona Press, Tuscon, AZ. 513 pp.

Cáceres–Martínez, C. and S. García–Bustamante. 1990. Cultivo piloto de ostion *Crassostrea gigas* (T.) en costales sobre estantes en la zona intermareal en la Bahía Magdalena, B.C.S., influencia de la densidad sobre el crecimiento. Pp. 269–278 *in* La aquacultura en México. De los conceptos a la producción. (Lanza–Espino, G. and J. Arredondo–Figuera, eds.) Instituto de Biologia, Universidad Autónoma de México, Mexico City, Mexico.

Casas–Valdez, M.M. 1987. Distribución en tiempo y espacio de las especies de sardina y macarela en Bahía Magdalena, B.C.S., México. Investig. Mar. CICIMAR, 3(2): 11–30.

———, G. Ponce–Díaz, A. Hérnandez–Llamas, M.A. González–Ojeda, F. Galván–Magaña, E. Guzmán–Vizcarra, S. Hernández–Várquez, A. Vélez–Barajas, and A. Sui–Qui. 1996. Recursos pesqueros y acuícolas de Baja California Sur: estado actual y perspectivas de aprovechamiento y desarollo. Pp. 1–14 *in* Estudio del potencial pesquero y acuícola de Baja California Sur. (Casas–Valdez, M.M. and G. Ponce–Díaz, eds.), Semarnap, Gob. del Edo. de B.C.S. FAO, UABCS, CIBNOR, CICIMAR–I.P.N., CRIP y Cet. Del Mar La Paz.

Casillas, R., R. Ruiz, F.J. Magallon, J. Arvizu, and G. Portillo. 1988. Crecimiento invernal de camaron azul (*Penaeus stylirostris*) sometido a condiciones de cultivo rustico en Puerto Chale, B.C.S., México. Rev. Latinoam. Acuicult., 36:62–71.

Castro–Aguirre, J.L. and R.T. Torres–Orozco. 1993. Consideraciones acerca del origen de la ictiofauna de Bahía Magdalena–Almejas, un sistema lagunar de la costa occidental de Baja California Sur, México. An. Esc. Nac. Cienc. Biol., Méx., 38:67–73.

Castro–Barrera, T. 1975. Ictioplankton de Bahía Magdalena, Baja California Sur. Cienc. Mar., 2(2): 10–36.

Chaves–Rosales, S. and S.C. Gardner. 1999. Recent harbour seal (*Phoca vitulina richardsi*) pup sightings in Magdalena Bay, Baja California Sur, Mexico. Aquat. Mamm., 25(3): 169–171.

Connolly, R.M. 1994. A comparison of fish assemblages from seagrass and unvegetated areas of a southern Australian estuary. Aust. J. Mar. Freshw. Res., 45(6): 1033–1044.

Cota–Meza, M.S., M.J. Haro–Garay, and R.V. Massé–Zendejas. 1992. Distribución y abundancia de quetognatos en el complejo lagunar de Bahía Magdalena Baja California Sur, México durante el ciclo estacional 1988–1989. Investig. Mar. CICIMAR, 7(2): 47–59.

Cruz–Agüero J. de la, F. Galvan–Magaña, L.A. Abitia–Cárdenas, J. Rodríguez–Romero, and F.J. Gutiérrez–Sánchez. 1994. Lista sistematica de los peces marinos de Bahía Magdalena, Baja California Sur (México). Cienc. Mar., 20(1): 17–31.

Dall, W.H. 1918. Descriptions of new species of shells, chiefly from Magdalena Bay, Lower California. Proc. Biol. Soc. Wash., 51:5–8.

Dawson, A.G. 1992. Ice age earth: late Quaternary geology and climate. Routledge, New York, NY. 293 pp.

Emilia–González, N. 1993. Moluscos endémicos del Pacífico de México. Pp. 223–252 *in* Biodiversidad marina y costera de México. (Salazar–Vallejo, S.I. and N.E. González, eds.) Com. Nal. Biodiversidad–Centro Investig, Quintana Roo, Mexico.

Environmental Systems Research Institute, Inc. 2002a. ArcView v3.3. Redlands, CA.

Environmental Systems Research Institute, Inc. 2002b. ArcGIS v8.2. Redlands, CA.

Félix–Pico, E.F. and F.A. García–Dominquez. 1993. Macrobenthos sublitoral de Bahía Magdalena, B.C.S. Pp. 389–410 *in* Biodiversidad marina y costera de México. (Salazar–Vallejo, S.I. and N.E. González, eds.) Com. Nal. Biodiversidad–Centro Investig, Quintana Roo, Mexico.

———, H.A. Salaices–Polanco, F.M. Alvarez, and A. Alvarez. 1986. Informe final: ecologia de la fauna macrobentónica litoral de las costas de Baja California Sur. CICIMAR –Inst. Nac. Pesca. La Paz, B.C.S., 43 pp.

Félix–Uraga, R., R.M. Alvarado–Castillo, and R. Carmona–Piña. 1996. The sardine fishery along the western coast of Baja California, 1981–1994. CalCOFI, 37:188–192.

Flores–Castanon, A. 1980. Prospeccion de los camarones comerciales (genero *Penaeus*) en el sistema lagunario Bahía Magdalena–Almejas, B.C.S. Mem. Simp. 2 Latino Americano Acuacultura, 1: 1303–1360.

Folk, R.L. 1974. Petrology of Sedimentary Rocks. Hemphill Publishing Co, Austin, TX. 182 pp.

Frizzell, V.A. Jr. 1984. The geology of the Baja California Peninsula. Pp. 1–7 *in* Geology of the Baja California Peninsula. (Frizzell, V.A., ed.), Soc. Econ. Paleontol. Mineral. Pac. Sec. 39.

Funes–Rodríguez, R., R. González–Armas, and R. Avendaño–Ibarra. 1998. Distribución y abundancia de las larvas de peces en el sistema lagunar de Bahía Magdalena–Almejas, Baja California Sur, México. Hidrobiológica., 8(1): 55–66.

Galván–Magaña, F., F. Gutiérrez–Sánchez, L.A. Abitia–Cárdenas, and J. Rodríguez–Romero. 2000. The distribution and affinities of the shore fishes of the Baja California Sur lagoons. Pp. 383–398 *in* Aquatic ecosystems of Mexico: status and scope. (Munawar, M., S.G. Lawrence, I.F. Munawar, and D.F. Malley, eds.) Backhuys Publishers, Leiden, The Netherlands.

Gárate–Lizárraga, I. 1992. Variación espacio–temporal de la abundancia fitoplanctónica y de la estructura de las asociaciones microfitoplanctónicas en el Sistema Laguna Magdalena–Almejas, durante 1984–1986. Masters Thesis. CICIMAR–Inst. Nac. Pesca. La Paz. B.C.S., 84 pp.

——— and D.A. Siqueiros–Beltrones. 1998. Time variation in phytoplankton assemblages in a subtropical lagoon system after the 1982–1983 "El Niño" Event (1984 to 1986). Pac. Sci., 52(1): 79–97.

——— and G. Verdugo–Díaz. 2001. Checklist of marine phytoplankton in a subtropical lagoon system in Baja California Sur, Mexico, from 1980 to 1989. Pp. 265–289 *in* Biological collections and biodiversity. (Rushton, B.S., P. Hackey, and C.R. Tyrie, eds.) Linn. Soc.–Westbury Books, London, England.

———, ———, and D.A. Siqueriros–Beltrones. 2001. Variations in phytoplankton assemblages during 1988–1989 in a subtropical lagoon system on the west coast of Mexico. Oceánides, 16(1): 1–16.

Garcia, E. 1973. Modificaciones al sistema de clasificación climática de Köppen. Universidad Nacional Autónoma de México, Mexico City, Mexico. 246 pp.

Garth, J.S. 1960. Distribution and affinities of the brachyuran Crustacea. Symposium: the biogeography of Baja California and adjacent seas. Syst. Zool., 9(3–4): 105–123.

Guardado–France, V.M. 1976. Estudios ecologicos de elasmobranquios en la zona de Bahía Magdalena, B.C.S. Bachelors Thesis. Universidad Autónoma de Baja California, Ensenada, B.C., Mexico. 135 pp.

Guerrero, R.R., D.R. Cervantes, and I.A. Jiménez. 1988. Nutrient variation during a tidal cycle at the mouth of a coastal lagoon in the Northwest of Mexico. Indian J. Mar. Sci., 3:235–237.

Gutiérrez–Sánchez, F.J. 1997. Ecologia de peces de fondos blandos del complejo lagunar Bahía Magdalena, B.C.S., México. Masters Thesis. CICIMAR, La Paz, Mexico. 84 pp.

Gutiérrez–Uribe, M.C. 1987. Composición específica de la captura de "escama" (pesqueria artisanal) en Bahía Magdalena, Baja California Sur, México. Masters Thesis. Universidad Nacional Autónoma de México, Mexico City, Mexico. 61 pp.

Hall, C. 1964. Shallow water marine climates and molluscan provinces. Ecology, 45(2): 226–234.

Hastings, P.A. 2000. Biogeography of the tropical eastern Pacific: distribution and phylogeny of chaenopsid fishes. J. Linn. Soc. Lond. Zool., 128:319–335.

Hendrickx, M.E. 1993. Crustáceos decápodos del Pacífico Mexicano. Pp. 271–318 *in* Biodiversidad marina y costera de México. (Salazar–Vallejo, S.I. and N.E. González, eds.) Com. Nal. Biodiversidad–Centro Investig, Quintana Roo, Mexico.

Hewitt, R. 1981. Eddies and speciation in the California Current. CalCOFI, 22:96–98.

Hubbs, C.L. 1948. Changes in the fish fauna of western North America correlated with changes in ocean temperature. J. Sears Found. Mar. Res., 7(3): 459–482.

Hubbs, C. 1960. The marine vertebrates of the outer coast. Symposium: the biogeography of Baja California and adjacent seas. Syst. Zool., 9(3–4): 134–147.

Ibarra–Obando, S.E., V.F. Camacho–Ibar, J.D. Carriquiry, and S.V. Smith. 2001. Upwelling and lagoonal ecosystems of the dry Pacific coast of Baja California. Pp. 315–330 *in* Ecological studies. Vol. 144: coastal and marine ecosystems of Latin America. (Seeliger, U. and B. Kjerfve, eds.) Springer–Verlag, Berlin, Germany.

INEGI. 2000. Anuario estadistco del estado de Baja California Sur. Mexico City: Instituto Nacional de Estadistica, Geografia, e Informatica.

Inman, D.L. and E.C. Nordstrom. 1971. On the tectonic and morphologic classification of coasts. J. Geology., 79:1–21.

Koch, V., J.M. Mazón–Suástegui, F. Sinsel, M. Robles–Mungaray, and D. Dunn. 2005. Lion's paw scallop (*Nodipecten subnodosus*, Sowerby 1835) aquaculture in Bahía Magdalena, Mexico: effects of population density and season on juvenile growth and mortality. Aquaculture Res., 36(5): 505–512.

Lambeck, K. and J. Chappell. 2001. Sea level through the last glacial cycle. Science, 292:679–686.

Lankford, R.R. 1977. Coastal lagoons of Mexico. Their origin and classification. Pp. 182–216 *in* Estuarine processes. Volume II: circulation, sediments, and transfer of material in the estuary. (Wiley, M.L., ed.) Academic Press, New York, NY.

Lluch–Belda, D., M.E. Hernández–Rivas, R. Saldierna–Martínez, and R. Guerrero–Caballero. 2000. Variabilidad de la temperatura superficial del mar en Bahía Magdalena, B.C.S. Oceánides, 15(1): 1–23.

Love, M.S., C.W. Mecklenburg, T.A. Mecklenburg, and L.K. Thorsteinson. 2005. Resource inventory of marine and estuarine fishes of the west coast and Alaska: a checklist of north Pacific and Artic Ocean species from Baja California to the Alaska–Yukon border. United States Geological Survey, Biological Resources Division, Seattle, WA. 276 pp.

Lynn, R.J. and J.J. Simpson. 1987. The California Current System: the seasonal variability of its physical characteristics. J. Geophys. Res., 92(C12): 12947–12966.

———, F.B. Schwing, and T.L. Hayward. 1995. The effect of the 1991–1993 ENSO on the California Current system. CalCOFI, 36:57–71.

MacMahon, J.A. 1997. Deserts. The National Audubon Society Nature Guides. Alfred A. Knopf, Inc, New York, NY. 640 pp.

Maeda–Martínez, A.N., P. Ormart, L. Mendez, B. Acosta, and M.T. Sicard. 2000. Scallop growout using a new bottom–culture system. Aquaculture, 189:73–84.

Margalef, R. 1969. Comunidades planctónicas en lagunas litorales. Pp. 545–563 *in* Memoires de un simposio internacional de lagunas y costeras. (Ayala, A. and F.B. Phleger, eds.) Universidad Nacional Autónoma de México–United Nations Educational, Scientific and Cultural Organization, Mexico City, Mexico.

Mariano–Meléndez, E. and C.J. Villavicencio–Garayzar. 1998. Cuatro tiburones y una raya en la costa noroccidental de México. Rev. Biol. Trop., 46(2): 465–467.

Mathews, C.P. 1975. El desarrollo de la zona de Bahía Magdalena. Un panorama biosocio–economico en una region en pleno desarrollo. Cienc. Mar., 2(1): 47–50.

Mathews, C. and J. Druck–Gonzalez. 1974a. Potencial pesquero y estudios ecológicos de Bahía Magdalena I. La existencias de camarón con referencia especial al camarón de roca o camarón japonés. Cienc. Mar., 2(1): 51–57.

——— and ———. 1974b. Potencial pesquero y estudios ecológicos de Bahía Magdalena III. La existencias de rayas con especial interés a las ya aprovechadas. Cienc. Mar., 2(1): 67–72.

——— and J. Espinoza. 1974. Potencial pesquero y estudios ecológicos de Bahía Magdalena IV. La distribución y abundancia de las existencias de pescado de escama. Cienc. Mar., 2(1): 73–76.

——— and V. Guardado–France. 1974. Potencial pesqueros y estudios ecológicos de Bahía Magdalena II. Las existencias de gatas. Heterodontidae. Cienc. Mar., 2(1): 60–66.

McLain, D.R. and D.H. Thomas. 1983. Year–to–year fluctuations of the California Countercurrent and effects on marine organisms. CalCOFI, 24:165–181.

McLean, J.H. 1969. Marine shells of southern California. Los Angeles Co. Mus. Nat. Hist. Sci. Ser. 24. Zool. 11. 104 pp.

McRoy, C.P. and C. Helfferich. 1977. Seagrass ecosystems. Marcel Dekker. Inc., New York, NY. 314 pp.

Morales–Bojórquez, E. 2002. Teorema de Bayes aplicado a la estimación del rendimiento de la sardina Monterrey (*Sardinops sagax caeruleus* Girard) de Bahía Magdalena, Baja California Sur, México. Cienc. Mar., 28(2): 167–179.

Morrissey, J.F. and S.H. Gruber. 1993. Habitat selection by juvenile lemon sharks, *Negaprion brevirostris*. Environ. Biol. Fishes., 38:311–319.

National Climatic Data Center. 1994. Comprehensive Ocean–Atmosphere Data Set. National Oceanic and Atmospheric Administration. www.ncdc.noaa.gov/oa/climate/coads/.

National Imagery and Mapping Agency (NIMA). 1998. Chart #21121. Bahía Magdalena including Bahía Santa María, Bahía Almejas, and Bahía Santa Marina, Reston, VA.

Nienhuis, H. and R. Guerrero–Caballero. 1985. A quantitative analysis of the annual phytoplankton cycle of the Magdalena lagoon complex (Mexico). J. Plankton Res., 7(4): 427–444.

——— and ———. 1986. Biomasa y distribución del fitoplancton entre 1980 y 1984 en Bahía Magdalena, Baja California Sur, Mexico. CICIMAR–Inst. Nac. Pesca. La Paz. Mexico. Atlas No. 5.

Obeso–Nieblas, M., J.H. Gaviño–Rodriguez, and Á.R. Jiménez–Illescas. 1999. Modelación de la marea en el sistema lagunar Bahía Magdalena–Almejas, B.C.S., México. Oceánides, 14(2): 79–88.

Palomares–García, R. 1992. Analisis de la taxocenosis de los copepodos en el complejo lagunar de Bahía Magdalena–Almejas, B.C.S., durante 1985–1986. Cienc. Mar., 18(3): 71–92.

——— and J. Gómez–Gutiérrez. 1996. Copepod community structure at Bahía Magdalena, Mexico during El Niño 1983–1984. Estuar. Coast. Shelf Sci., 43:583–595.

———, A. Martínez–López, R. De Silva–Dávila, R. Funes–Rodríguez, M.A. Carballido–Carranza, R. Avendaño–Ibarra, A. Hinojosa–Medina, and G.A. López–Ibarra. 2003. Biological effects of El Niño 1997–98 on a shallow subtropical ecosystem: Bahía Magdalena, Mexico. Geofisica International, 42(3): 455–466.

Phleger, F.B. and G.C. Ewing. 1962. Sedimentology and oceanography of coastal lagoons in Baja California, Mexico. Geo. Soc. Am. Bull., 73:145–182.

Postma, H. 1965. Water circulation and suspended matter in Baja California lagoons. Neth. J. Sea Res., 2: 566–604.

Ramírez–Espinosa, J.A. 1990. Distribución y abundancia poblacional del lobo marino (*Zalophus californianus* Lesson, 1828) en la Isla Margarita, B.C.S., México durante la temporada otoñal. Pp. 7–24 *in* Estudio sobre el lobo marino en el noroeste de México. Sec. de Pesca, Mexico.

Ramírez–Rodríguez, E.M. 1987. Analisis preliminary de las pesquerias artesanales del area de Bahía Magdalena, B.C.S. durante 1982 y 1983. Mem. 5 Simp. Biol. Mar. Univ. Autón. B.C.S., 149–154.

Rice, D.W., A.A. Wolman, and D.E. Withrow. 1981. Gray whales on the winter grounds in Baja California. Rep. Int. Whal. Comm., 31:477–489.

Riosmena–Rodríguez, R. and J.L. Sánchez–Lizaso. 1996. El limite sur de distribución de *Zostera marina* L. y Phyllospadix torreyi Watson para el noroeste Méxicano. Oceanides, 11(1): 45–48.

Robertson, A.I. and N.C. Duke. 1987. Mangroves as nursery sites: comparisons of the abundance and species composition of fish and crustaceans in mangroves and other nearshore habitats in tropical Australia. Mar. Biol., 96:193–205.

Robinson, C.J. and S. Gomez–Aguirre. 2004. Tidal stream use by the red crab *Pleuroncodes planipes* in Bahía Magdalena, Mexico. J. Exp. Mar. Biol. Ecol., 308:237–252.

———, J. Gómez–Gutiérrez, R. Félix–Uraga, and V. Arenas–Fuentes. 2000. Seasonal hydro–acoustical observations of small pelagic fish behaviour in Bahía Magdalena, Mexico. Aquat. Living Resour., 13(1): 11–18.

Salazar–Hermoso, F. and C. Villavicencio–Garayzar. 1999. Abundancia relative de la guitarra *Rhinobatos productus* (Ayres, 1856) (Pisces: Rhinobatidae) en Bahía Almejas, Baja California Sur, de 1991 a 1995. Cienc. Mar., 25(3): 401–422.

Salinas–Zavala, C.A., A.L. Leyva–Contreras, D. Lluch–Belda, and E. Diaz–Rivera. 1990. Distribución geográfica y variabilidad climática de los regimens pluviométricos en Baja California Sur, México. Atmósfera, 3:217–237.

Sánchez–Ortiz, C.A. and J. Gómez–Gutiérrez. 1992. Distribucion y abundancia de los estadios planctonicos de la jaiba *Callinectes bellicosus* (Decapoda: Portunidae), en el complejo lagunar Bahía Magdalena, B.C.S., México. Rev. Investig. Cient., 3(1): 47–60.

Sánchez–Rodríguez, I., M.C. Farjardo–Leon, and C. Oliveiro–Pantoja. 1989. Estudio floristico estacional de las algas en Bahía Magdalena, Baja California Sur, México. Investig. Mar. CICIMAR, 4(1): 35–48.

Santamaría–Gallegos, N.A., J.L. Sánchez–Lizaso, and R. Riosmena–Rodríguez. 2003. Life strategies of subtropical eelgrass *Zostera marina* L. populations in southern Baja California: its southern limit distribution along East Pacific. Gulf Mex. Sci., 21(1): 130–131.

Sedlock, R.L. 2003. Geology and tectonics of the Baja California peninsula and adjacent areas. Geo. Soc. Am. Spec. Pap., 374:1–41.

Shumilin, E., G.D. Rodríguez–Meza, D. Sapozhnikov, S. Lutsarev, and J. Murillo de Nava. 2005. Arsenic concentrations in the surface sediments of the Magdalena–Almejas Lagoon Complex, Baja California Peninsula, Mexico. Bull. Environ. Contam. Toxicol., 74:493–500.

Soule, J. 1960. The distribution and affinities of the littoral marine bryozoa (Ectoprocta). Symposium: the biogeography of Baja California and adjacent seas. Syst. Zool., 9(3–4): 100–104.

Spencer, J.E. and W.R. Normark. 1979. Tosco–Abreojos fault zone: a Neogene transform plate boundary within the Pacific margin of southern Baja California, Mexico. Geology, 7:554–557.

——— and ———. 1989. Neogene plate tectonic evolution of the Baja California Sur continental margin and the southern Gulf of California, Mexico. Pp. 489–497 *in* Geology of North America. The eastern Pacific Ocean and Hawaii. Winterer, E.L., D.M. Jussong, and R.W. Decker (EDITORS). 1989 Geol. Soc. Am., Boulder, Colorado.

Takasaki, T. 1913. Los recursos pesqueros de Bahía Magdalena, B.C.S. Traducción por H. Chapa–Saldaña (1962) y republicado en: S.I.C. Dir. Gen. Pesca and Ind. Com., Dep. Est. Biol. Pesq. Trab: Div. #23, 3:1–27.

Torres–Orozco, R.E. and J.L. Castro–Aguirre. 1992. Registros de peces tropicales en el complejo lagunar de Bahía Magdalena–Almejas, Baja California Sur, México. Anales Inst. Biol. Univ. Autón. México, Ser. Zool., 63(2): 281–286.

Valentine, J. 1966. Numerical analysis of marine molluscan ranges on the extratropical northeastern Pacific shelf. Limnol. Oceanogr., 11:198–211.

Villavicencio–Garayzar, C.J. 1995. Distribución temporal y condición reproductiva de las rayas (Pisces: Batoidea) capturadas comercialmente en Bahía Almejas, Baja California Sur (México). Rev. Investig. Cient. Univ. Autónoma de Baja California Sur, 6(12): 1–12.

Wentworth, C.K. 1922. A scale of grade and class terms for clastic sediments. J. Geol., 30:377–392.

Young, E. 2001. State intervention and abuse of the commons: fisheries development in Baja California Sur. Ann. Assoc. Am. Geographers., 91(2): 283–306.

Accepted for publication 11 December 2007.

Bull. Southern California Acad. Sci.
107(1), 2008, pp. 25–32

Abundance and Size Composition of Vermilion Rockfish, *Sebastes miniatus* (Jordan and Gilbert 1880), from Sport Fishing Catches of San Quintín, Ensenada, Baja California, México

María Amparo Rodríguez-Santiago[1] and Rosales-Casián Jorge Adrián[2]

[1]*Facultad de Ciencias Marinas, Universidad Autónoma de Baja California, Km 106 carretera Tijuana-Ensenada, Ensenada, B.C., México, C.P. 22800*
[2]*Centro de Investigación Científica y de Educación Superior de Ensenada, B.C., División de Oceanología, Departamento de Ecología, Km 107 carretera Tijuana-Ensenada, Ensenada, B.C., México. C.P. 22800*

Abstract.—The vermilion rockfish (*Sebastes miniatus*) is part of an extended group of fish species named rockcods or rockfishes that are distributed in waters of the Californias. This species is a common and popular fish caught by the commercial and recreational fishers. This study shows the results of the vermilion rockfish monitoring from the recreational fishing at San Quintín, Baja California, México during 2005. A total of 71 boats were counted from one-day (Saturday) monthly visits, and a total of 1,026 vermilion rockfish was registered, 60.4% of those were measured and weighed. Catches were highest during April (25.9 ± 3.7 SE vermilions per boat), lowest (5.8 ± 3.9 SE) in November and for the overall year averaged 14.5 ± 1.3 SE. The sizes of vermilions rockfish were from 240 mm TL caught in November, and the biggest (680 mm TL) in December; the annual mean size was 448 mm TL (±2.4 mm SE). The recreational fishing at San Quintín, B.C. targeted almost all adult vermilion rockfishes, with only five individuals, of those measured, under the first maturity size (310 mm TL).

Introduction

Many fish species are shared between Baja California and California waters. The rockfishes (*Sebastes* spp.) comprised a large proportion of catches in the nearshore recreational fishery (Stephens et al. 2006), and commercial catch off California (Eschmeyer et al. 1983, Love 1996).) Off Baja California, the rockfishes group also makes up a substantial part of both the commercial (Hernandez-Hernandez 2002; Rosales-Casián and González-Camacho 2003), and partyboat catch (Rodríguez-Medrano 1993). A great diversity of rockfishes (56 species) is found within the Southern California Bight, and although little information exists about the Pacific coast of Baja California, the number of species off northern and perhaps central Baja California is similar but species composition is different (Love et al. 2002).

Called vermilion rockfish, red rock cod or named simply "reds", *Sebastes miniatus*, is a common fish species that is caught from, both, the coastal commercial and the recreational fishing; is found from Prince William Sound, Alaska south to central Baja California, Mexico (O'Connell et al. 1992), but are most abundant from central California southwards (Love 1996, Love et al. 2002).

Adults inhabit rocky reefs, kelp forests and canyons at depths of 15–467 m, but commonly at depths of 50–150 m, and can be found on artificial structures such as wastewater discharge pipes and oil drilling platforms (Love et al. 1990; 2002; 2003).

Vermilion rockfish showed strong site fidelity, but they may move from reef to reef, particularly in deep water, and may be associated with following schools of prey, such as squid (Lea et al 1999; Love 1981; Love 1996).

This species can grow to 91 cm TL and 6.8 kg, with an age record of 60 years old of one individual (Eschmeyer et al. 1983). The first maturity for male is at 32 cm TL and females begin to mature at 31 cm, all are mature at 37 and 47 cm, respectively and are single brooders (Love et al 1990). Half population is mature at 8 years, and peak spawning months are September at northern California and November in southern California (Ven Tresca 1992). Female vermilion rockfish appear to be reproductively active throughout the year and gravid was most abundant in September, and spent individuals were observed in the highest percentage during October–November (Lea et al 1999).

New larvae are pelagic and found near the surface frequently associated with algae (Ven Tresca 1999; 2001). Young-of-the-year appears in inshore shallow water beginning in February (Love 1996), and prefer a mix of hard-and-soft bottoms (Eschmeyer et al. 1983, Love 1996). Pelagic young feed small crustaceans (Ven Tresca 1992), and adults prey on other fishes (anchovies, lanternfishes, small rockfishes), octopi, squids, krill (Love 1996), and crustaceans as euphausiids, copepods, mysids, amphipods and carideans (Lea et al. 1999).

In California and during 2004, a total of 212 metric tons were landed of vermilion rockfish from the recreational fishing across 1,100 miles of coastline, and was seventh in the list of fish species abundance (CDFG 2005). In 2005 for south central California coast, vermilion rockfish was caught in a number of 1,218 individuals by the partyboats, and was second only after the *S. mystinus*, the blue rockfish, with 2,751 individuals landed (Stephens et al. 2006).

Little information about *S. miniatus* from Baja California is available. In a study of the recreational fishing at Bahía de Todos Santos (Ensenada, B.C.) realized during 1991, this species was not recorded in the first ten fish species caught, and classified as occasional fishing with an occurrence of 60% in boats (Rodriguez-Medrano 1993). This study is part of the catch characterization of the recreational fishing from San Quintín, Ensenada, Baja California, México. The objective of this study is to determine the abundance and the length structure of the vermilion rockfish caught by the partyboats throughout 2005.

Methods

This study was conducted monthly from January to December 2005. San Quintín was selected from the Pacific coast of northern Baja California because of its importance as a fishing camp and we detected a recent increase in recreational fishing activity (Rosales-Casián and Gonzalez-Camacho, 2003). San Quintín is situated about two hundred kilometers south of Ensenada on the Transpeninsular Highway, and the boat ramp at El Molino Viejo (Old Mill) is used for both recreational and commercial boats. The recreational fishery at San Quintín is mainly conducted with small boats (up to 8 m long). This fishery involves a variety of ground and pelagic species from habitats up to 100 m deep. Sampling was conducted one day per month (Saturday) and we attempted to process the catch of the largest possible number of boats.

The identification of *S. miniatus* was according to Miller and Lea (1972). Vermilion rockfish catch from the individual boats were counted and measured upon arrival and before of their cleaning. The total and standard lengths (mm-TL, SL) were obtained with one measurement board with divisions to millimeter. If boats arrived while we were working fish, the vermilions were only counted.

Table 1. Numbers of vermilion rockfish caught and monthly mean catch per boat and per angler from the recreational fishing at San Quintín, B.C. México, (SE: standard error).

MONTH	NO. BOATS	TOTAL FISH	MIN.	MAX.	Catch per Boat	SE	Anglers	Catch per Angler	SE
January	5	55	1	33	11.0	5.79	12	4.6	1.41
February	5	46	1	15	9.2	2.65	12	3.8	1.25
March	5	106	12	27	21.2	2.78	10	10.6	1.39
April	9	233	16	47	25.9	3.65	23	10.1	1.71
May	8	185	12	40	23.1	3.27	21	8.8	1.39
June	5	33	3	16	6.6	2.42	12	2.8	0.72
July	5	64	2	31	12.8	5.79	11	5.8	2.18
August	8	80	1	28	10.0	3.85	17	4.7	1.81
September	7	55	1	18	7.9	2.48	15	3.7	1.26
October	4	75	3	35	18.8	8.05	13	7.8	3.56
November	4	23	2	11	5.8	1.93	10	2.3	0.55
December	6	71	5	19	11.8	2.43	16	4.4	1.45
Total	71	1026	1	47	14.5	1.33	172	6.0	0.57

Abundance was converted to catch per unit effort (CPUE) by dividing the monthly number of fishes by the monthly number of boat trips (Rosales-Casián and Gonzalez-Camacho 2003). Also, we calculated the fish per angler by dividing the number of monthly vermilions by the number of anglers per month. We used a Kruskal-Wallis test (ANOVA) to detect monthly mean differences.

The total lengths (TL-mm) were grouped by 20 mm length-classes and their frequencies were presented for all individuals and by seasons: winter (January–March), spring (April–June), summer (July–September), fall (October–December). Each monthly sample included four to nine boats, and over seasons increased to 14 to 22 boats. Sizes were transformed to ($\log_{10}$) and to determine seasonal differences in length means we used an ANOVA.

Results

During our visits at San Quintín in 2005, the catch of 71 boats and a total number of 1,026 vermilion rockfish was recorded; vermilions were caught in all months with the lowest number of boats recorded in October and November (four boats, each), and the highest in April with nine boats (Table 1). The minimum catch per vessel was one vermillion (January, February, August and September) to a maximum of 47 individuals by one boat in April. The lowest total monthly catch was recorded during November in four boats (23 vermillion rockfishes), and the highest total monthly catch was 233 individuals by nine boats during April, which caught from 16 to 47 individuals catched by singles boats (Table 1).

The catch per boat for the overall year averaged 14.5 ± 1.3 SE (SE: standard error) vermilions per boat (Table 1), with the highest mean computed for April (25.9 ± 3.7 SE vermilions per boat), and lowest (5.8 ± 3.9 SE vermilions per boat) for November. The distribution of the vermilion catch per boat on the complete year shows a large increase during March–May, with the highest mean during April; another peak was observed during October, and two lowest at June (6.6 ± 2.4 SE vermilions per boat) and November (5.8 ± 1.9 SE) (Fig. 1). There was a significant difference in the mean catch (vermilions per boat) between months of 2005 (Kruskal-Wallis $H = 27.719$, $p = 0.0036$). The catch per angler presented a peak during March to May (Table 1); the annual mean catch per

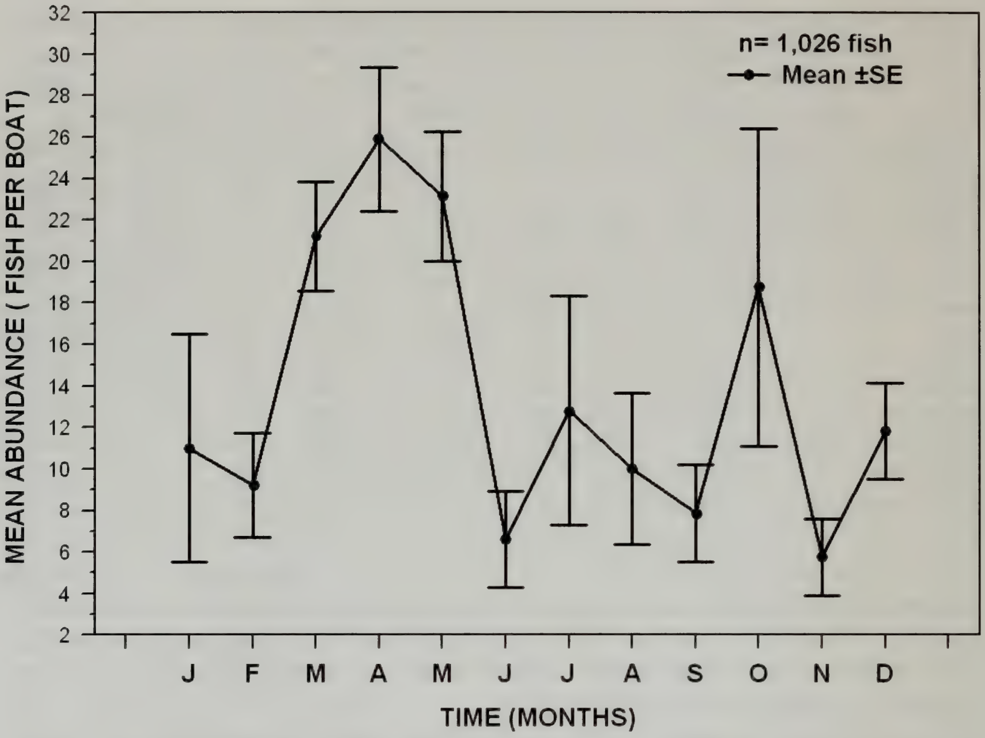


Fig. 1. Monthly mean abundance of vermilion rockfish (fish per boat) caught by sportfishing boats at San Quintín, B.C., México.

angler was 6.0 vermilions per angler (±0.6 SE), with the highest mean in March (10.6 vermilions per angler ± 1.4 SE) and the lowest during June (2.8 ± 0.7 SE) and November (2.3 ± 0.6 SE); the Kruskal-Wallis test showed differences in the monthly mean catch per angler (H = 25.064 p = 0.0089).

A total of 620 vermilion rockfish (60.4% of total) were measured and weighed. The smallest fish was 240 mm TL caught during November, and the largest (680 mm TL) was found in December. The annual mean size was 448 mm TL (±2.4 mm SE), with the minimum mean size found in February (366.4 mm TL) and the maximum (477.5 mm TL) in May (Table 2). There was a significant difference in monthly mean TL (ANOVA, F = 19.025, p = 0.000).

The overall size distribution of the vermilion rockfish shows a mode at the size class of 400–419 mm TL (Fig. 2), with a main group size from 380–479 mm TL that represented 64.8% of the total fish measured. By seasons, the smallest sizes (<260 mm TL) were present in the catch of fall (Fig. 3), and specifically during November; The largest mean size was found for summer (mean: 466.9 mm ± 3.5 SE), and the lowest for winter (mean: 422.2 mm ± 3.8 SE); Differences between length mean by seasons were found (ANOVA, F = 21.201, p = 0.000).

Discussion

Vermilion rockfish are popular in both the recreational and commercial fisheries (Love et al. 1990, Love 1996). They are highly prized by party and private vessel anglers throughout California with the majority of catches occurring from Monterey Bay south.

Table 2. Total length (mm) and monthly length mean of vermilion rockfish caught by recreational boats at San Quintín, Baja California, México.

MONTH	TOTAL FISH	MIN. LT (mm)	MAX. LT (mm)	MEAN	SD	SE
January	22	350	490	388.6	36.8	7.8
February	29	310	400	366.4	21.8	4.0
March	105	320	560	444.7	38.1	3.7
April	100	345	615	457.6	68.4	6.8
May	145	380	580	477.5	52.5	4.4
June	30	360	520	446.8	43.1	7.9
July	34	390	650	442.1	51.8	8.9
August	30	305	485	414.3	39.5	7.2
September	38	410	610	473.8	74.5	12.1
October	40	300	550	452.6	55.1	8.7
November	23	240	460	391.3	59.4	12.4
December	24	370	680	454.6	68.5	14.0
Total	620	240	680	448.0	60.9	2.4

Adults are taken primarily by gill net and hook and line, and make up a substantial part of the rockfish commercial catch off California (Eschmeyer et al. 1983, Love 1996). In the San Quintín, Baja California region, the vermilion rockfish is the most common fish species found in the recreational fishing industry. In our 2005 fish study, the vermilion rockfish was recorded in all months, with a peak catch from March to May, just after the storm season. The decrease in vermilion rockfish from June to September occurs as

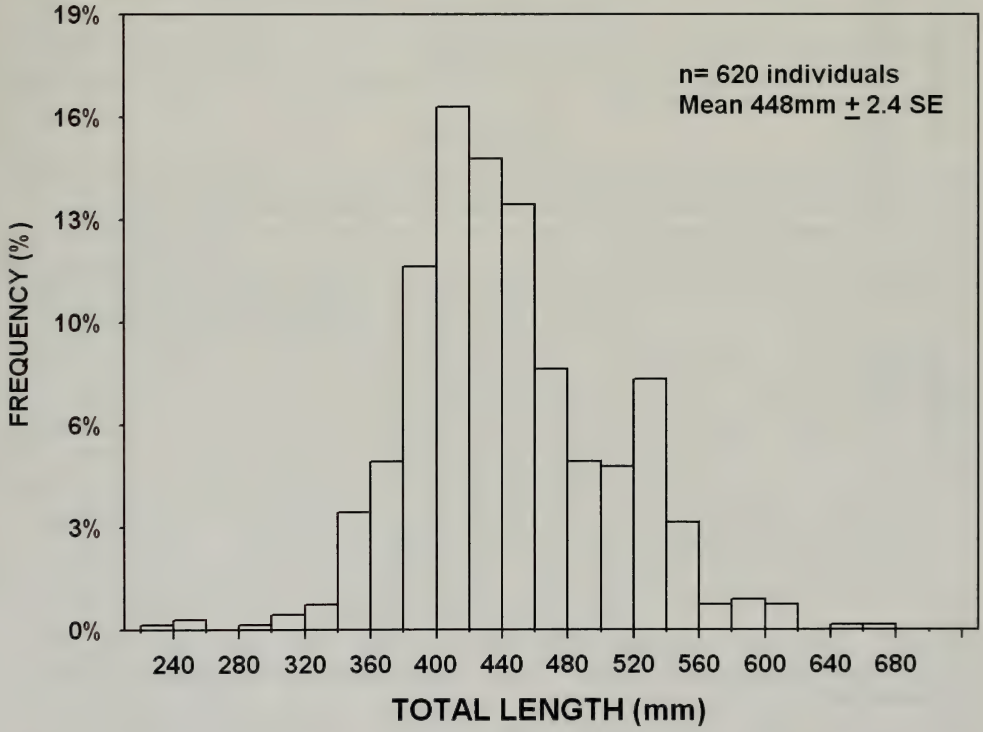


Fig. 2. Total length (mm) distribution (20 mm TL class) of vermilion rockfish from recreational fishing at San Quintín, B.C., México.

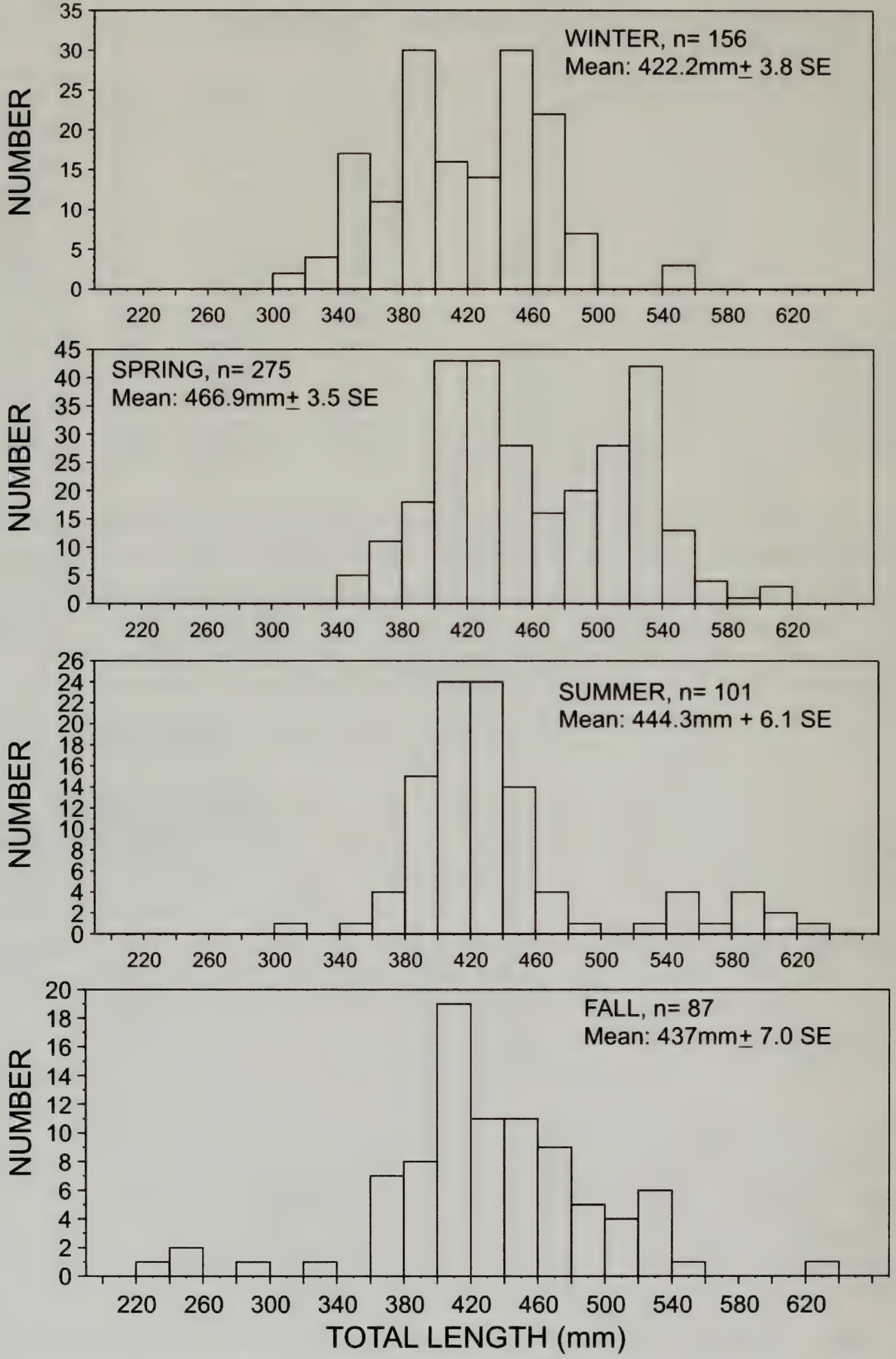


Fig. 3. Seasonal size distribution (20 mm TL class) of vermilion rockfish from recreational fishing at San Quintín, B.C., México.

fisherman turn to big pelagic fishes such as yellowtail, albacore, dorado, yellowfin tuna, barracuda, and marlin.

Small vessels comprise the recreational fishing fleet of San Quintín. It is strongly influenced by weather conditions, and this should be considered since there was a small number of fishing trips. With respect to the limits of fish caught, only six of the 71 boats landed the bigger numbers (31 to 48) of vermilion rockfishes at San Quintín, and considering that boats are rented by two to four anglers, the fish numbers per fisherman are lesser (6.0 ± 0.6 SE) than the mean number per boat (14.5 vermilions per boat). Vermilion rockfish mature at about 310 mm TL (Love et al. 1990). In the San Quintín catch, five individuals were caught under this length (240, 250, 260, 300 and 305 mm TL) only, and the first three individuals registered in November. This may be due to the recruitment of subadults to the adult habitats or population.

In Baja California, the rockfishes are important part of the commercial nearshore fishing (Rosales-Casián and González-Camacho 2003), in the recreational fishing were not recorded among the first ten fish species caught. However, it was taken with a frequency of occurrence of 60% among all boats surveyed (Rodríguez-Medrano 1993). Rockfish are also common fish species found at the Ensenada Seafood Market (Hernández-Hernández 2002). The recreational fishing at San Quintín, B.C., can be considered a healthy fishery by the reduced number of boat trips and the number of vermilion rockfish per boat landed. Practically, in 2005 almost all vermilion rockfishes were adult (>310-mm LT), with only five individuals under the first maturity size, and with a suitable annual mean size of 448 mm LT.

Acknowledgments

Thanks to Rubi Ruz-Cruz for her technical assistance during the monitoring visits to San Quintín. This study was financed with internal funds of CICESE.

Literature Cited

California Department of Fish and Game. 2005. Review of some California fisheries for 2004: Coastal pelagic finfish, market squid, sea urchin, lobster, spot and ridgeback prawn, groundfish, highly migratory species, ocean salmon, nearshore live-fish, pacific herring, and recreational. CalCOFI Rep., 46:10–31.

Eschmeyer, W.N., E.S. Herald, and H. Hammann. 1983. A field guide to Pacific Coast fishes of North America. Houghton Mifflin, Boston, Massachusetts. 336 pp.

Hernández-Hernández, A. 2002. Composición específica de los peces escama comercializados en el Mercado de Mariscos del Puerto de Ensenada, Baja California, México. Facultad de Ciencias Biológicas, Universidad Autónoma del Estado de Morelos, Cuernavaca, Morelos (México). 60 pp.

O'Connell, V.A., D.A. Gordon, A. Hoffmann, and K. Hepler. 1992. Northern range extension of the vermilion rockfish (*Sebastes miniatus*). Calif. Dep. Fish Game, 78:173.

Lea, R.N., R.D. McAllister, and D.A. Ven Tresca. 1999. Biological aspects of nearshore rockfishes of the genus *Sebastes* from central California. Calif. Dept. Fish Game Fish. Bull. 177, 109 pp.

———, ———, and ———. 1999. Biological aspects of nearshore rockfishes of the genus *Sebastes* from central California. Calif. Dep. Fish Game Fish. Bull. 177, 109 pp.

Love, M.S. 1981. Evidence of movements of some deepwater rockfishes (Scorpaenidae: genus *Sebastes*) of southern California. Cal. Fish Game., 67:246–249.

———. 1996. Probably more than you want to know about the fishes of the Pacific coast. Really Big Press, Santa Barbara, California. 215 pp.

———, P. Morris, M. McCrae, and R. Collins. 1990. Life history aspects of 19 rockfish species (Scorpaenidae: *Sebastes*) from the southern California Bight. NOAA Tech. Rep. NMFS 87, 38 pp.

———. 1996. Probably more than you want to know about the fishes of the Pacific coast. Really Big Press, Santa Barbara, California. 215 pp.

———, M. Yoklavich, and L. Thorsteinson. 2002. The rockfishes of the Northeast Pacific. University of California Press, Los Angeles. 405 pp.

———, D.M. Schroeder, and M. Nishimoto. 2003. The ecological role of Oil and Gas production platforms and natural outcrops on fishes in Southern and Central California: A synthesis of information. U.S. Department of Interior, U.S. Geological Survey, Biological Resources Division, Seattle, Washington, 98104, OCS Study MMS 2003–032.

Miller, D.J. and R.L. Lea. 1972. Guide to the coastal marine fishes of California. Cal. Dept. Fish Game. Fish Bull., 157:235.

Rodríguez-Medrano, M. del C. 1993. Descripción y análisis de la pesca deportiva en Bahía de Todos Santos, Ensenada, B. C. M.S. thesis. CICESE, 88 pp.

Rosales-Casián, J.A. and J.R. González-Camacho. 2003. Abundance and importance of fish species from artisanal fishery on the Pacific coast of Northern Baja California. Bull. Southern California Acad. Sci., 102(2):51–65.

Stephens, J., D. Wendt, D. Wilson-Vandenberg, J. Carroll, R. Nakamura, E. Nakada, S. Rienecke, and J. Wilson. 2006. Rockfish resources of the South Central California coast: analysis of the resource from partyboat data, 2000–2005. CalCOFI Reports, 47:140–155.

Ven Tresca, D.A. 1992. Vermilion rockfish. *In* W.S. Leet, C.M. Dewees, and C.W. Haugen (eds.), California's Living Marine Resources and Their Utilization. California Sea Grant College Program. Davis, California, UCSGEP-92-12:123–124, 257 pp.

———. 2001. Vermilion rockfish. *In* W.S. Leet, C.M. Dewees, R. Klingbiel, and E.J. Larson (eds.), California's Living Marine Resources: A status report. California Department of Fish and Game. University of California Agriculture and Natural Resources. Sea Grant Publication, SG01-11: 189–190, 591 pp.

Accepted for publication 20 August 2007.

Bull. Southern California Acad. Sci.
107(1), 2008, pp. 33–40

Levels of the Organophosphorus Pesticide Diazinon in the Chollas Creek Watershed, San Diego CA, since Its Phase-Out in 2004

Kayo Watanabe,[1] Karen Franz,[2] and Richard M. Gersberg[1]*

[1]*Graduate School of Public Health, San Diego State University, 5500 Campanile Drive, San Diego CA 92182/4162*
[2]*San Diego Coastkeeper, 2825 Dewey Road, Suite 200 San Diego CA, 92106*

Abstract.—In 2004, the organophosphorus pesticide, diazinon, was phased-out for all residential uses in the United States. The objective of this study was to determine the temporal trend of diazinon levels in the Chollas Creek, CA watershed since the phase-out of this pesticide. Stormwater samples from Chollas Creek were collected during seven storm events in 2006–2007. The median diazinon level for all samples was 0.13 μg/L. Statistical analysis using the Kruskal-Wallis test revealed no statistically significant ($p=0.765$) spatial difference among any of the sampling sites. Correlational analysis (using the Spearman's rho test) revealed that there was no significant association between antecedent dry days and median diazinon levels ($p=0.383$, rho=0.393). Additionally, no association between storm event precipitation ($p=0.355$, rho=-0.414), median storm event intensity ($p=0.585$, rho=-0.252), or annual cumulative precipitation ($p=0.760$, rho=0.143) was observed. Trend analysis of diazinon levels (1998–2005) showed that levels in this watershed have declined with a negative slope of 0.0002 μg/L per year, and statistical analysis (using the Mann-Whitney U test) showed there was a significant decline in levels after the pesticide's phase-out in 2004 ($p<0.05$).

Chollas Creek is located within a highly urbanized area of San Diego County, CA and drains into San Diego Bay, San Diego, California. The drainage area is 6585.4 hectares (3753.9 hectares in North fork, 2831.6 hectares in South fork) (San Diego Region Water Quality Control Board [SDRWQCB] 2002a). It has highly variable flows, the highest of which are associated with storm events. Toxicity tests using the water flea *Ceriodaphnia dubia* have indicated that stormwater flows in Chollas Creek are toxic to aquatic life, and toxicity identification evaluations (TIEs) showed that diazinon was responsible for this toxicity (Southern California Coastal Water Research Project [SCCWRP] 1999). Such consistent toxicity, and levels of organophosphorus pesticides in urban runoff in the state California, has led regulators to add at least 32 California streams to their list of impaired water bodies (303 d list) (Schiff and Sutula 2004).

Diazinon is an organophosphorus insecticide that until recently was common in indoor, residential, landscape and agricultural applications. Although, the breakdown rate of diazinon in the aqueous phase is pH dependent, with rapid degradation occurring under increasingly acidic conditions, its average half-life in neutral waters is about six months (EXTOXNET, 2003). Diazinon concentrations in Chollas Creek during storm events have caused violations of the "toxicity" and "pesticide" water quality objectives

---

* Corresponding Author, rgersber@mail.sdsu.edu, (619)594-2905.

(SDRWQCB 2002a). Accordingly, Chollas Creek was placed onto the List of Water Quality Limited Segments in 1996 (commonly referred to as the 303(d) List) (SDRWQCB 2002a). Clean Water Act Section 303 (d) requires the Regional Board to develop a Total Maximum Daily Load (TMDL) for waters on this list (SDRWQCB 2002b). The SDRWQCB has since developed the Chollas Creek TMDL to begin to address water quality impairment due to diazinon (SDRWQCB 2002b).

On December 31, 2002, the United States Environment Protection Agency (USEPA) started to impose restrictions on many uses of diazinon in the United States under the revised risk assessment and agreement between the USEPA and diazinon registrants. The agreement included indoor uses and all uses on lawns gardens, and turf (USEPA 2001). The agreement mandated that technical registrants reduce the amount of diazinon produced for outdoor non- agricultural uses by 50% or more by the start of 2003, and sales to retailers were stopped on August 31, 2003. Any remaining diazinon at retailers was returned to manufacturers beginning on December 31, 2004. The overall objective of this study was to determine the temporal trend of diazinon levels in the Chollas Creek watershed since the phase-out of this pesticide in 2004, in order to determine if this regulatory strategy has been effective in this urban watershed.

Materials and Methods

Sampling Method

Stormwater samples from Chollas Creek watershed were collected as grab samples during storm events on March 2, March 29, April 14, May 22, and December 16 of 2006, and February 19, and April 20 of 2007 from four sites (Fig. 1). Sampling times varied in relation to both the start and duration of the storm event as shown in Table 1. The samples, collected using one liter amber glass containers, were transported on ice to the laboratory after collection, and were stored at 4°C until testing. Samples were then analyzed using enzyme-linked immunosorbent assay (ELISA) (Sullivan and Goh 2000) within seven days of collection.

ELISA Analytical Chemistry

A diazinon EnviroGard Kit (Strategic Diagnostics, Newark, Delaware) was used for the ELISA analyses performed in this study. Concentrations of diazinon in samples were derived by reading optical densities of the calibration standards using a spectrophotometer at 450 nm (Spectra max PLUS 384 Molecular Devices). The method has a limit of detection of 0.022 μg/L for diazinon (Strategic Diagnostics, Newark, Delaware).

Precipitation Data

Precipitation data from San Diego Lindbergh international airport were taken from National Oceanic and Atmospheric Administration (NOAA, Retrieved June 6, 2007, from: http://www.ncdc.noaa.gov/oa/mpp/).

Data Analysis

For present study (2006–2007), lab duplicates for each sample site were analyzed. SPSS Version14.0 was performed for statistical analysis. The median diazinon level at each site was calculated and Kruskal-Wallis test (Kruskal and Wallis 1958) was used for spatial trend analysis. The Spearman's rho test (Spearman 1904) was used to determine correlation between a single median diazinon level of all sites for each storm event, and the number of antecedent dry days (the number of days without rain or with less than

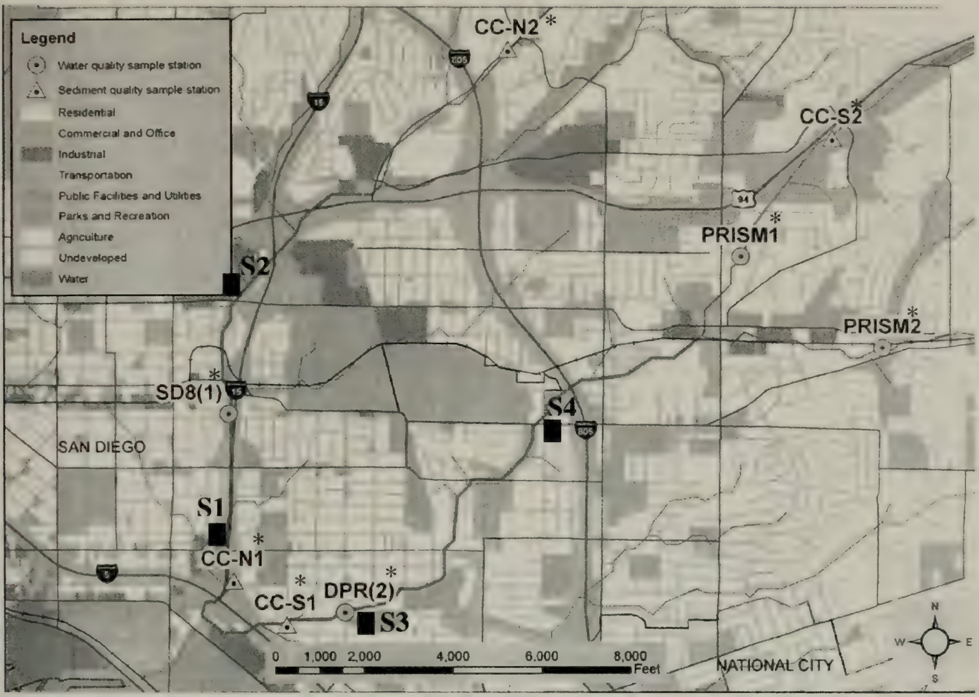

Legend
Water quality sample station
Sediment quality sample station
Residential
Commercial and Office
Industrial
Transportation
Public Facilities and Utilities
Parks and Recreation
Agriculture
Undeveloped
Water
CC-N2
805
15
CC-S2
94
PRISM1
S2
PRISM2
SD8(1)
S4
805
SAN DIEGO
S1
CC-N1
5
CC-S1
DPR(2)
S3
0 1,000 2,000 4,000 6,000 8,000 Feet
NATIONAL CITY
N
W
E
S

Fig. 1. Sampling sites on Chollas Creek, and associated land use of the Chollas Creek watershed. Note. *DPR(2), PRISM1, PRISM2, SD8(1) CC-N1, CC-N2, CC-S1, CC-S2 were sampling sites from Weston Solutions, Inc., 2006.

0.1 inch in water year), storm event precipitation, intensity (the amount of precipitation in centimeters per hour during storm event), and annual cumulative precipitation. Annual cumulative precipitation was calculated based on a water year, from October to September of the following year. Flow measurements for Chollas Creek during this study were not available.

A Mann-Whitney U test (Mann and Whitney 1947) was performed to compare diazinon levels before the pesticide's phase-out period (1998–2004) to levels after the phase-out was completed (2005), and a Kendall's test (Kendall 1955) was performed to determine if the declining trend in levels of diazinon from 1998 through 2005, has been significant.

Quality Assurance (QA) and Quality Control (QC) Procedures

Quality control samples consisted of field blanks, field duplicate samples, and lab duplicate samples. Precision for all samples were within the objective for diazinon of 25% which was previously established (San Diego Baykeeper 2005), except for a single sample (Site 4 on March 29, 2006) which showed precision of 26%. Overall precision was 4.96% for all tests. Additionally, QA/QC procedures consisted of enrichment of natural Chollas Creek waters at each sampling site, with at least two different levels (100 ppt and 200 ppt or 500 ppt) of diazinon spiked into these samples, in order to determine the accuracy of the ELISA method. Accuracy of the ELISA test for diazinon-spiked samples for each rain event ranged from 67.8% to 204.2%, with a median value of 115.0% for all diazinon-enriched samples. This indicated that there was no significant inhibition by materials in the river water which could significantly mask the ELISA results.

Table 1. Correlations between diazinon levels and rainfall parameters.

Start of rain event (Time)	Site	Date sampled	Time	Median diazinon (ug/L)	Anteced-ent dry days	Precipita-tion (cm)	Intensity (cm/hour)	Cumulative precipitation (cm)
27 Feb, 2006	S1	2 Mar, 2006	11:55	0.052	2	2	0.076	2.2
(18:00)	S2		12:47					
28 Mar, 2006	S1	29 Mar, 2006	9:24	<0.022	8	0.99	0.1	5.8
(20:00)	S2		8:40					
	S3		9:00					
	S4		9:46					
14 Apr, 2006	S1	14 Apr, 2006	15:45	0.12	10	0.58	0.17	7.7
(6:00)	S2		14:50					
	S3		16:00					
	S4		15:26					
22 May, 2006	S1	22 May, 2006	10:06	0.042	38	2	0.2	9.9
(3:00)	S2		9:25					
	S3		10:17					
	S4		9:50					
16 Dec, 2006	S1	16 Dec, 2006	21:52	0.19	6	0.41	0.076	3.2
(7:00)	S2		21:40					
	S3		22:08					
	S4		21:04					
17 Feb, 2007	S1	19 Feb, 2007	11:36	0.23	19	1.8	0.11	7.6
(10:00)	S2		11:00					
	S3		11:48					
	S4		11:15					
20 Apr, 2007	S1	20 Apr, 2007	17:20	0.39	57	0.76	0.089	9.6
(4:00)	S2		16:44					
	S3		17:27					
	S4		17:00					

Results

Overall, seven storm events were sampled at sites S1 and S2, and six were sampled at sites S3 and S4. No hydrograph data was available, and sample times varied among the storm events, but our study showed that significant levels of diazinon may still be found in the Chollas Creek watershed even several years after the complete phase-out of the pesticide in 2004. Median levels of diazinon at sample sites in the Chollas Creek Watershed, from March 2, 2006 to April 20, 2007 are shown in Table 2. Diazinon levels ranged from as low as the detection limit (0.022 μg/L) at S1 (National Ave), S2 (Market

Table 2. Diazinon levels at each sample site for the study period from March 2006 through April 2007.

Sample site	N	Mean	Standard Deviation	Median	Minimum	Maximum	% of acute criterion exceedance	% of chronic criterion exceedance
S1	7	0.13	0.13	0.08	<0.022	0.4	43	71
S2	7	0.15	0.15	0.12	<0.022	0.42	57	57
S3	6	0.15	0.13	0.14	<0.022	0.38	57	71
S4	6	0.19	0.12	0.19	0.042	0.36	71	71
All Sites				0.13				

Note: Acute criterion 0.08 μg/L; Chronic criterion 0.05 μg/L

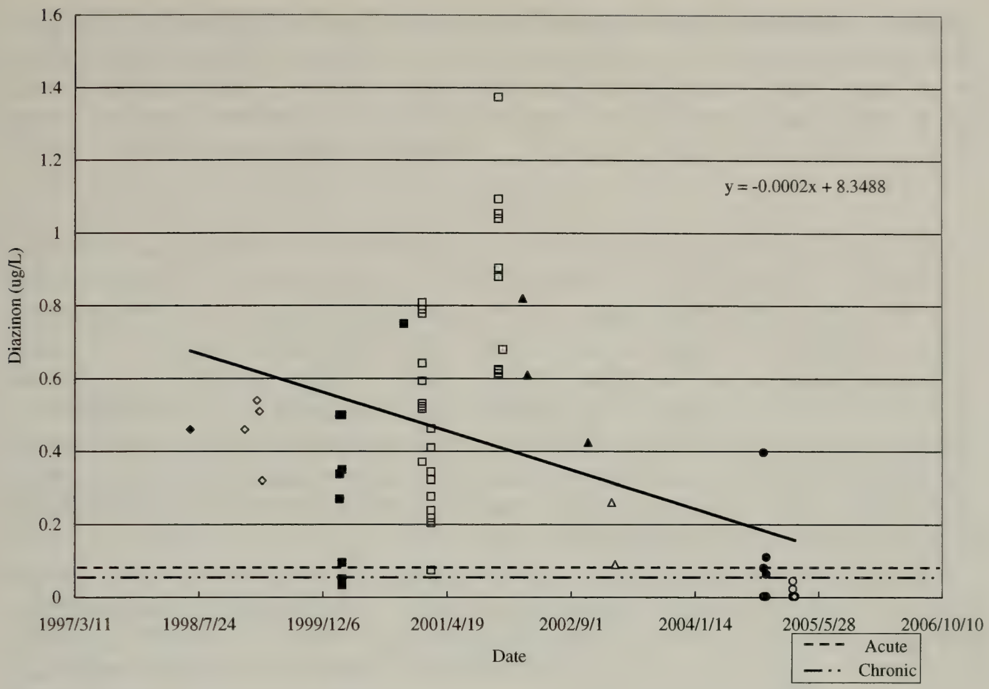


Fig. 2. Trend analysis between diazinon level (μg/L) and year between 1998 and 2005. Note. Each data point represents the mean for all samples and all sites for that particular study. ◆ URS Greiner Woodward Clyde 1999; ◇ URS Greiner Woodward Clyde 1999 and Southern California Coastal Project, 1999; ■ MEC Analytical Systems Inc. 2002, and Project Clean Water 2004; □ MEC Analytical Systems Inc. 2002, Project Clean Water 2004; ▲ Project Clean Water 2004; △ Project Clean Water 2004; ● Weston Solutions Inc. 2006; ○ Weston Solutions Inc. 2006; * present study, – present study. Kendall's Test $p=0<0.05$ tau=−0.352.

St), and S3 (38th St) on March 29, 2006, to 0.42 μg/L at S2 (Imperial Ave) on April 20, 2007. The median level of all sites and dates combined was 0.13 μg/L. This value exceeded both the chronic (0.050 μg/L) and acute (0.080 μg/L) criteria listed by SDRWQCB (2002a). The acute criterion was exceeded 43% to 71% of the 26 total times sampled, and the chronic criterion was exceeded 57% to 71%of the total times sampled.

S4 had the highest median concentration of diazinon (0.19 μg/L) (Table 2). However, statistical analysis using Kruskal-Wallis test revealed no statistically significant ($p=0.765$) difference among any of the sampling sites. In order to test whether buildup and wash off of diazinon in the Chollas Creek watershed could account for the temporal pattern of diazinon observed in total seven storm events, correlational analysis between the number of antecedent dry days and median diazinon level of all sites for each storm events was performed (Table 1). No significant association between antecedent dry days (2–57 days) and the median diazinon levels (<0.022–0.39 μg/L) ($p=0.383$, rho=0.393) was found. Additionally, no association between storm event precipitation (0.41–2.0 cm) ($p=0.355$, rho=−0.414), median storm event intensity (0.076–0.20 cm/hour) ($p=0.585$, rho=−0.252), or annual cumulative precipitation (2.2–9.9 cm) ($p=0.760$, rho=0.143) was observed (Table 1).

This historical diazinon data for Chollas Creek, as represented by the diazinon levels at all sites sampled for each past study, is shown in Figure 2. Since flow-associated variability may complicate the analysis, only studies based on flow-weighted composite sampling in the Chollas Creek watershed were plotted. Between 1998 and 2005, diazinon levels significantly declined with a negative slope of 0.0002 µg/L per year (Kendall's test, $p<0.05$, tau$=-0.352$). Moreover, a Mann-Whitney U test of the temporal data showed that there has been a significant ($p<0.05$) decline in diazinon levels when levels before the phase-out (1998–2004), were compared to levels after the phase-out (2005).

Discussion

Our study found that the median level of diazinon in 2006–2007 (three years after the phase-out) for all sites and dates combined was 0.13 µg/L, and this value still exceeded both the chronic (0.050 µg/L) and acute (0.080 µg/L) criteria listed by SDRWQCB (2002a). Diazinon has been shown to exert acute and chronic toxicity in aquatic ecosystems (Menconi & Cox 1994; USEPA 2005). A study based on *Ceriodaphnia* survival was done in Chollas Creek and TIEs showed that diazinon was the principal cause of toxicity in this watershed (SCCWRP 1999). Apparently, despite the phase-out in the 2004, diazinon is still at levels that may exert adverse ecological effects, although studies conducted in the watershed since 2004 using *Ceripdaphnia*, showed no evidence of persistent toxicity (Project Clean Water 2007).

After the complete phase-out of the use of diazinon in 2004, a study on the Chollas Creek watershed showed that median diazinon levels were 0.16 µg/L, but by 2005, they had been reduced to levels below the diazinon criteria for both acute (0.080 µg/L) and chronic (0.050 µg/L) exposure (Weston Solutions Inc. 2006). However, the present study on Chollas Creek found that the acute and chronic criteria were still exceeded by 43%–71%, and 57%–71%, respectively, in 2006 and 2007. This might reflect the fact that the shelf life of diazinon is five to seven years (Missouri Environment and Garden 2003), and consumers might have continued to use purchased quantities of diazinon in the Chollas Creek watershed despite its complete phase-out in 2004.

Statistical analysis using Kruskal-Wallis test revealed no statistically significant ($p=0.765$) difference among any of the sampling sites in Chollas Creek Watershed. This may be due to the fact that levels of diazinon in the Chollas Creek watershed were somewhat variable both spatially and as a function of the particular characteristics of a given rain event. A more robust data set may be necessary to reveal significant spatial differences. The specific relationship of land use to levels of diazinon in urbanized watersheds has not been well assessed. Although Hoffman et al. (2000) found that the insecticide use was similar in urban and agricultural areas based on water samples from eight urban streams from across the United States, Schiff and Sutula (2004) found that diazinon levels in a mixed agricultural land use exceeded the residential and commercial land use categories by one to two orders of magnitude in an urbanized watershed of southern California. A study using toxicity identification evaluations in the Salinas River, CA, between 1998 and 2000, found significant *Ceriodaphnia dubia* mortality in 87% of the samples from a channel draining an urban/agricultural watershed, and 100% of the sample from a channel agricultural surface furrow runoff (Hunt et al. 2003), suggesting that both land use types may be major contributors. The fact that the Chollas Creek watershed is located in an urban area where nearly 70% of the land use is residential (Woodward-Clyde International-Americas 1998), as opposed to the Salinas River watershed composed of mostly agricultural lands, suggests that residential land uses may continue to be a significant and major source of diazinon.

Bumgardner et al. (1994) showed that build-up and wash off effects of pollutants could be identified by linear regression analyses, and found that for certain pollutants, wash off by rainfall does deplete the pollutant supply (accumulated by build-up processes) available for wash-off in subsequent rain events. The fact that there was no statistically significant association between antecedent dry days and diazinon levels (Table 1) may reflect the limited number of rain events we sampled or that levels in stormwater do not follow a simple buildup-wash off model.

Trend analysis (Fig. 2) showed that diazinon levels have been decreasing since 1998 to 2005, with negative slope of 0.0002 μg/L per year (Kendall's test, $p<0.05$, tau $=-0.352$), and statistical analysis (Mann-Whitney U test) showed there has been a significant decline in diazinon levels since the pesticide's phase-out in 2004 ($p<0.05$). A study on diazinon in surface waters in the City of Denton, Texas (Banks et al. 2005) showed a similar statistically significant ($p<0.0001$) decrease during the years (from 2001 and 2004) spanning the USEPA phase-out period. The National Water Quality Assessment (NAWQA) done by the United States Geological Survey between 1997 through 2004 found that diazinon concentrations decreased significantly ($p<0.05$) in five of seven in urban and mixed land use streams in the northeastern U.S. by the end of its phase-out period in 2004, with a median decrease in these NAWQA streams of 28% (Philips et al. 2006). Our analysis of historical diazinon data for the Chollas Creek watershed (Fig. 2) showed that a decline of 93% was observed over the same period (1998–2004). Apparently, the decline of diazinon levels since the start of the phase-out has been greater in the Chollas Creek Watershed than in northeastern U.S. (Philips et al. 2006), but levels of diazinon still persist that may exert ecotoxicity.

Acknowledgments

We would like to thank the City of San Diego for the opportunity to collaborate with us on the Chollas Creek Enhancement Project and for providing funding for this work. Special thanks to Walter Hayhow, Bassem Ebaid, and Rika Shuto for technical assistance.

Literature Cited

Banks, E.K., H.D. Hunter, and J.D. Wachal. 2005. Diazinon in surface waters before and after a federally-mandated ban. Science of the Total Environment, 350:86–93.

Bumgardner, J., A. Ruby, M. Walker, and D. Brent. 1994. Discharge characterization of urban storm water runoff using continuous simulation. Pp. 243–56 *in:* Current practices in modeling the management of storm water impacts. (W. James, ed.), Lewis Publishers, xiii + 469 pp.

Hoffman, R.S., P.D. Capel, and S.J. Larson. 2000. Comparison of pesticides in eight urban streams. Environmental Toxicology and Chemistry, 19:2249–2258.

Hunt, W.J., S.B. Anderson, M.B. Phillips, N.P. Nicely, S.R. Tjeerdema, and M.H. Puckett, et al. 2003. Ambient Toxicity due to chlorpyrifos and diazinon in a central California coastal watershed. Environmental Monitoring and Assessment, 82:83–112.

Kendall, G.M. 1955. Rank Correlation Methods, Second Edition. Hafner, New York.

Kruskal, H.W. 1958. Ordinal Measures of Association. Journal of the American Statitical Association, 53: 814–861.

Mann, B.H. and R.D. Whitney. 1947. On a Test of Whether One of Two Random Bariables isStochastically Larger than the Other. Annals of Mathematical Statistics, 18:50–60.

MEC Analytical Systems, Inc. 2002. 1999–2001 Chollas Creek Watershed Monitoring Final Report. Carlsbad, CA. ii + 45 pp.

Menconi, M. and C. Cox. 1994. Hazard assessment of the insecticide diazinon to aquatic organisms in the Sacramento-San Joaquin river system. Report 94-1. California Department of Fish and Game, Sacramento, CA. vi + 57 pp.

Missouri Environment and Garden. 2003. Those #@$% Leftover Pesticides. News for Missouri's Gardens, Yards, and and Resources 9(11). Retrieved from http://agebb.missouri.edu/hort/meg/archives/v9n11/

National Oceanic and Atmospheric Administration (NOAA).n.d.. Edited Local Climatological Data. National Climatic Data Center. Retrieved June 6, 2007, from http://www.ncdc.noaa.gov/oa/mpp/

Philips, J.P., W.S. Ator, and A.E. Nystrom. 2006. Recent NAWQA Data Show that Diazinon Concentrations in Some Northeast Streams have Declined Following Recent Reductions in Use. U.S. Geological Survey The Quality of Our Nation's Waters -Pesticides in the Nation's Streams and Ground Water, 1992–2001: Circular, 1291:134–144.

Project Clean Water. 2004. San Diego Bay Watershed Urban Runoff Management Program 2002–03 Annual Report. Retrieved March 29, 2007 from: http://www.projectcleanwater.org/html/wurmp_san_diego_bay.html

Project Clean Water. 2007. San Diego Bay Watershed Urban Runoff Management Program 2005–2006 Annual Report. Retrieved December 5, 2007 from: http://www.projectcleanwater.org/html/wurmp_san_diego_bay.html

San Diego Baykeeper. 2005. Chollas Creek Enhancement Project Citizen Diazinon Monitoring Component Quality Assurance Project Plan. San Diego, CA. 26 pp.

Schiff, K. and M. Sutula. 2004. Organophosphorus pesticides in storm-water runoff from southern California (USA). Environmental Toxicology and Chemistry, 23(8):1815–1821.

SDRWQCB. 2002a. Resolution No. R9-2003-0123:Chollas Creek Total Maximum Daily Load. San Diego, CA. 7 pp.

SDRWQCB. 2002b. Technical report for Total Maximum Daily Load for Diazinon in Chollas Creek Watershed San Diego County Final. San Diego, CA. 67 pp.

Southern California Coastal Water Research Project. 1999. Characterization of storm water toxicity in Chollas Creek, San Diego. Westminster, CA. ix + 52 pp.

Spearman, C. 1904. The Proof and Measurement of Association Between Two Things. American Journal of Psychology, 15:72–101.

Sullivan, J.J. and S.K. Goh. 2000. Evaluation and Validation of a Commercial ELISA for Diazinon in Surface Waters. Journal of Agriculture and Food Chemistry, 48:4071–4078.

URS Greiner Woodward Clyde. 1999. 1998–1999 City of San Diego and co-permittee NPDES storm water monitoring program report. San Diego, CA.

U.S. Environment Protection Agency. 2005. Aquatic Life Ambient Water Criteria Diazinon Final. Office of Water Office of Science and Technology, Washington DC. vii + 78 pp.

U.S. Environment Protection Agency. 2001. Diazinon revised risk assessment and agreement with registrants. Office of Pesticide Programs: Prevention, Pesticides and toxic Substances (7506C). Retrieved January 1, 2007, from www.epa.gov./pesticides.

Weston Solutions Inc. 2006. 2004–2005 Water and Sediment Quality Monitoring Data Summary for Chollas Creek, Final Report. Carlsbad, CA. i + 65 pp.

Woodward-Clyde International Americas. 1998. 1996–97 City of San Diego and co-permittees NPDES storm water monitoring program report. San Diego, CA.

Accepted for publication 12 October 2007.

Bull. Southern California Acad. Sci.
107(1), 2008, pp. 41–43

Research Note

First Occurrence of A Pacific Crevalle Jack, *Caranx caninus*, North of San Diego, California

Eric F. Miller[1] and Michael D. Curtis

MBC Applied Environmental Sciences, 3000 Red Hill Ave., Costa Mesa, California 92626

Pacific crevalle jack (*Caranx caninus*) is common throughout the tropical waters of the eastern Pacific Ocean (Eschmeyer et al. 1983, Nelson et al. 2004). It was believed that a single crevalle jack species (*C. hippos*) was circumglobal in its distribution, but Smith-Vaniz and Carpenter (2007) divided the species into three taxa, *C. hippos* (Atlantic, mainly western), *C. caninus* (eastern Pacific), and *C. fischeri* (eastern Atlantic). They described numerous meristic differences between the three species while maintaining them under the *C. hippos* complex. Throughout their tropical range, Pacific crevalle jack are often found in shallow inshore areas, including brackish waters (Eschmeyer et al. 1983). Along the eastern Pacific boundary, the northern range limit extends to San Diego Bay, California (Miller and Lea 1972; Eschmeyer et al. 1983; Love et al. 2005).

The northern range limit for Pacific crevalle jack was established with the collection of an individual in south San Diego Bay in March 1972 (Miller and Lea 1972; SIO [Scripps Institution of Oceanography] 72–69) during a period of warmer than normal sea surface temperatures (Lea and Rosenblatt 2000). Lea and Rosenblatt (2000) report a total of four individuals collected from southern California, all within San Diego Bay, with the last individual collected on 21 January 1998 (SIO 98–119), during the one of the most intense El Niño events of the twentieth century. The remaining two individuals were collected in May 1975 (SIO 75–383) and September 1984 (SIO 84–251), both in San Diego Bay.

El Niño Southern Oscillation (ENSO) events commonly transport more tropical species northwards along the Northeast Pacific Coast (Lea and Rosenblatt 2000), especially species known to aggregate around flotsam, such as jacks (Hunter and Mitchell 1966). While two carangid species (yellowtail jack [*Seriola lalandi*] and jack mackerel [*Trachurus symmetricus*]) are common to the Southern California Bight, Lea and Walker (1995) noted the record of 12 novel carangid species collected within southern California. Most of these occurrences were attributed to natural migrations associated with warm-water oceanographic events, although they did note the potential for anthropogenic introductions, especially of juveniles or adults carried north aboard sportfishing vessels, either as bait or alive within their holds.

On 5 December 1982, M. D. Curtis collected one juvenile Pacific crevalle jack during an impingement survey at Huntington Beach Generating Station in Huntington Beach, California. Initially preserved in 10% formalin, the specimen was later transferred to 90% ethanol for archiving in the MBC Applied Environmental Sciences voucher collection. The individual measured 83 mm standard length, with a total length of 100 mm (Table 1). Morphometric analysis compared favorably to measurements in Miller and Lea (1972) with the current specimen exhibiting the following fin spine/ray counts: anal fin III, 18, pectoral fin I, 21, and dorsal fin VII, 21 (Table 2). Furthermore, a high arch in

---

[1] Corresponding author: emiller@mbcnet.net

Table 1. Body length measurements of a juvenile Pacific crevalle jack, *Caranx caninus*.

Length	Measurement (mm)
Head Length	28
Standard Length	83
Fork Length	91
Total Length	100

Table 2. Morphometric analysis of current specimen and reported values from Miller and Lea (1972).

Morphometric	Miller and Lea, 1972	Current specimen
Anal Fin	II+I, 15–18	III,18
Pectoral Fin	I,18–21	I,21
Dorsal Fin	VII–VIII+I,18–23	VII,21
Gill Rakers	15–19	16

the lateral line over the pectoral fin was observed as well as dark vertical lines over the length of the body (Figure 1), consistent with the published description of a juvenile Pacific crevalle jack (Miller and Lea, 1972). The individual was donated to the Scripps Institution of Oceanography Marine Vertebrates Collection (SIO 07–71), which held the four previously reported California collections.

This specimen represents the first collection north of San Diego Bay, California. It is presumed this individual was present in the Huntington Beach, California area due to higher than normal seawater temperatures recorded during the ENSO event of 1982 (Lea and Rosenblatt 2000). This individual is substantially smaller than all of the previously known specimens. All previous collections were provided by fishermen, both commercial and recreational.

Acknowledgements

We would like to thank L.G. Allen and D.J. Pondella for confirming the identification of the specimen. We would also like to thank H. J. Walker for his curatorial assistance.

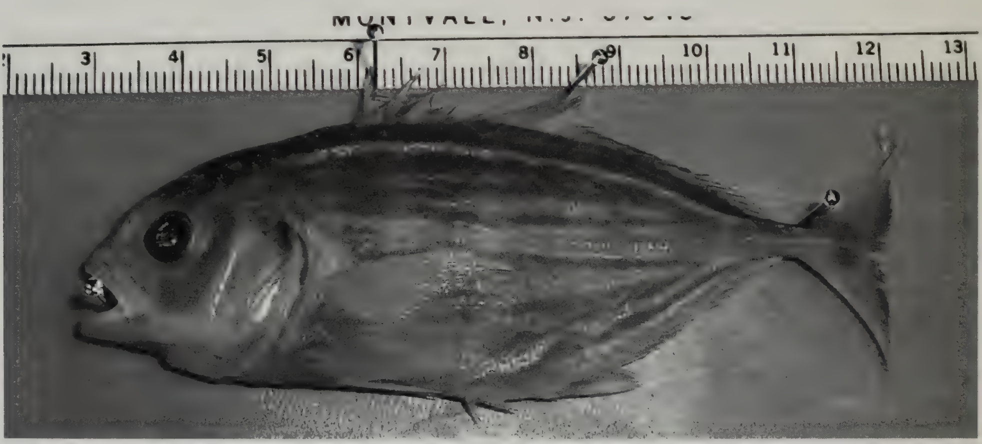


Fig. 1. Pacific crevalle jack, *Caranx caninus*, collected at Huntington Beach, California on 5 December 1982.

The manuscript was greatly improved by the comments of C. T. Mitchell, D.S. Beck, D.J. Pondella, and three anonymous reviewers.

Literature Cited

Eschmeyer, W.N., E.S. Herald, and H. Hammann. 1983. A field guide to Pacific coast fishes of North America. Houghton Mifflin Co, New York, NY. 336 pp.

Hunter, J.C. and C.T. Mitchell. 1966. Association of fishes with flotsam in the offshore waters of Central America. U.S. Fish. Bull., 66:13–29.

Lea, R.N. and R.H. Rosenblatt. 2000. Observations on fishes associated with the 1997–98 El Niño off California. CalCOFI, 41:117–129.

——— and H.J. Walker, Jr. 1995. Record of the bigeye trevally, *Caranx sexfasciatus*, and Mexican lookdown, *Selene brevoorti*, with notes on other carangids from California. Calif. Fish & Game, 81(3):89–95.

Love, M.S., C.W. Mecklenburg, T.A. Mecklenburg, and L.K. Thorsteinson. 2005. Resource Inventory of Marine and Estuarine Fishes of the West Coast and Alaska: A Checklist of North Pacific and Arctic Ocean Species from Baja California to the Alaska–Yukon Border. U. S. Department of the Interior, U. S. Geological Survey, Biological Resources Division, Seattle, Washington, 98104, OCS Study MMS 2005-030 and USGS/NBII 2005-001.

Miller, D.J. and R.N. Lea. 1972. Guide to the coastal marine fishes of California. Calif. Dept. Fish & Game. Fish Bull. 157. 249 pp.

Nelson, J.S., E.J. Crossman, H. Espinosa-Pérez, L.T. Findley, C.R. Gilbert, R.N. Lea, and J.D. Williams. 2004. Common and scientific names of fishes from the United States, Canada, and Mexico. American Fisheries Society, Special Publication 29, Bethesda, Maryland.

Smith-Vaniz, W.F. and K.E. Carpenter. 2007. Review of the crevalle jacks, *Caranx hippos* complex (Teleostei:Carangidae), with a description of a new species from West Africa. U.S. Fish. Bull., 105: 207–233.

Accepted for publication 11 December 2007.

INSTRUCTIONS FOR AUTHORS

The BULLETIN is published three times each year (April, August, and December) and includes articles in English in any field of science with **an emphasis on the southern California area**. Manuscripts submitted for publication should contain results of original research, embrace sound principles of scientific investigation, and present data in a clear and concise manner. The current AIBS *Style Manual for Biological Journals* is recommended as a guide for contributors. Consult also recent issues of the BULLETIN.

MANUSCRIPT PREPARATION

The author should submit at least two additional copies with the original, on 8½ × 11 opaque, nonerasable paper, double spacing the entire manuscript. Do not break words at right-hand margin anywhere in the manuscript. Footnotes should be avoided. **Manuscripts which do not conform to the style of the BULLETIN will be returned to the author.**

An abstract summarizing in concise terms the methods, findings, and implications discussed in the paper *must* accompany a *feature article. Abstract should not exceed 100 words.*

A feature article comprises approximately five to thirty typewritten pages. Papers should usually be divided into the following sections: abstract, introduction, methods, results, discussion and conclusions, acknowledgments, literature cited, tables, figure legend page, and figures. Avoid using more than two levels of subheadings.

A research note is usually one to six typewritten pages and rarely utilizes subheadings. Consult a recent issue of the BULLETIN for the format of *notes*. Abstracts are not used for notes.

Abbreviations: Use of abbreviations and symbols can be determined by inspection of a recent issue of the BULLETIN. **Omit periods after standard abbreviations:** 1.2 mm, 2 km, 30 cm, but Figs. 1–2. Use numerals *before* units of measurements: 5 ml, but nine spines (10 or numbers above, such as 13 spines). The metric system of weights and measurements should be used wherever possible.

Taxonomic procedures: Authors are advised to adhere to the taxonomic procedures as outlined in the International Code of Botanical Nomenclature (Lawjouw et al. 1956), the International Code of Nomenclature of Bacteria and Viruses (Buchanan et al. 1958), and the International Code of Zoological Nomenclature (Ride et al. 1985). Special attention should be given to the description of new taxa, designation of holotype, etc. Reference to new taxa in titles and abstracts should be avoided.

The literature cited: Entries for books and articles should take these forms.

McWilliams, K. L. 1970. Insect mimicry. Academic Press, vii+326 pp.

Holmes, T. Jr., and S. Speak.1971.Reproductive biology of Myotis lucifugus. J. Mamm., 54:452–458.

Brattstrom, B. H.1969.The Condor in California. Pp. 369–382 in Vertebrates of California. (S. E. Payne, ed.), Univ. California Press, xii+635 pp.

Tables should not repeat data in figures *(line drawings, graphs, or black and white photographs) or contained in the text.* The author must provide numbers and short legends for tables and figures and place reference to each of them in the text. Each table with legend must be on a separate sheet of paper. All figure legends should be placed together on a separate sheet. **Illustrations and lettering thereon should be of sufficient size and clarity to permit reduction to standard page size;** *ordinarily they* **should not exceed 8½ by 11 inches** in size and after final reduction lettering must equal or exceed the size of the typeset. All half-tone illustrations will have light screen (grey) backgrounds. Special handling such as dropout half-tones, special screens, etc., must be requested by and will be charged to authors. **As changes may be required after review, the authors should retain the original figures in their files until acceptance of the manuscript for publication.**

Assemble the manuscript as follows: cover page (with title, authors' names and addresses), abstract, introduction, methods, results, discussion, acknowledgements, literature cited, appendices, tables, figure legends, and figures.

A cover illustration pertaining to an article in the issue or one of general scientific interest will be printed on the cover of each issue. Such illustrations along with a brief caption should be sent to the Editor for review.

PROCEDURE

All manuscripts should be submitted to the Editor, Daniel A. Guthrie, W. M. Keck Science Center, 925 North Mills Avenue, Claremont, CA 91711. Manuscripts may be submitted by mail, or by e-mail to dguthrie@jsd.claremont.edu as a Word document. **Authors are requested to submit the names, addresses and specialities of three persons who are capable of reviewing the manuscript. Evaluation of a paper** submitted to the BULLETIN begins with a critical reading by the Editor; several referees also check the paper for scientific content, originality, and clarity of presentation. Judgments as to the acceptability of the paper and suggestions for enhancing it are sent to the author at which time he or she may be requested to rework portions of the paper considering these recommendations. The paper then is resubmitted on disk in word format and may be re-evaluated before final acceptance.

Proof: The galley proof and manuscript, as well as reprint order blanks, will be sent to the author. He or she should **promptly** and **carefully read** the proof sheets for errors and omissions in text, tables, illustrations, legends, and bibliographical references. He or she marks corrections on the galley (copy editing and proof procedures in *Style Manual*) and **promptly returns both galley and manuscript** to the Editor. Manuscripts and original illustrations will not be returned unless requested at this time. **All changes in galley proof attributable to the author (misspellings, inconsistent abbreviations, deviations from style, etc.) will be charged to the author. Reprint orders are placed with the printer, not the *Editor*.**

CONTENTS

Articles

A Review of the Physical and Biological Characteristics of the Bahía Magdalena Lagoon Complex (Baja California Sur, Mexico). Joseph J. Bizzarro 1

Abundance and Size Composition of Vermilion rockfish, *Sebastes miniatus* (Jordan and Gilbert 1880), from Sport Fishing Catches of San Quintín, Ensenada, Baja California, México. Maria Amparo Rodríguez-Santiago and Rosales-Casián Jorge Adrián 25

Levels of the Organosphosphorus Pesticide Diazinon in the Chollas Creek Watershed, San Diego CA, since Its Phase-Out in 2004. Kayo Watanabe, Karen Franz, and Richard M. Gersberg 33

Research Note

First Occurrence of a Pacific Crevalle Jack, *Caranx caninus*, North of San Diego, California. Eric F. Miller and Michael D. Curtis 41

Cover: Pacific Crevalle Jack, *Caranx caninus*.

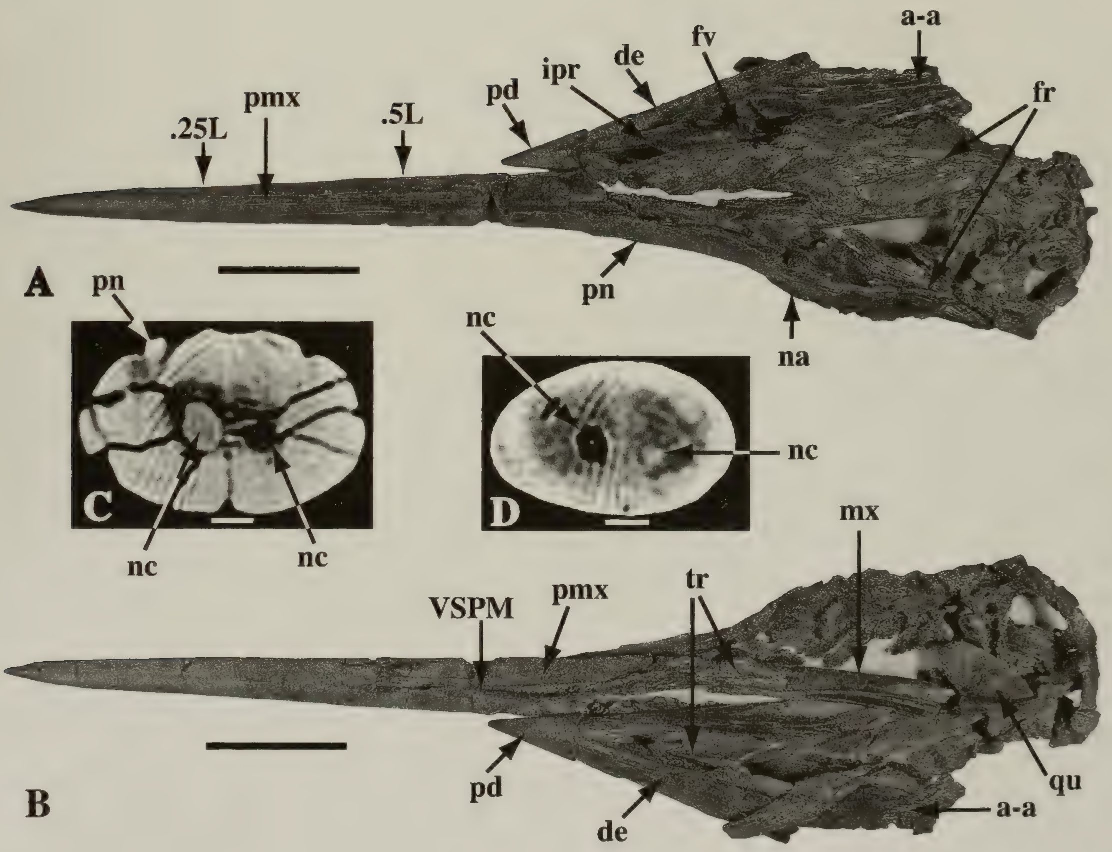
Serials
QH
1
.S69
v.107
no.2
24116-130

ISSN 0038-3872

SOUTHERN CALIFORNIA ACADEMY OF SCIENCES

BULLETIN

Volume 107 Number 2


a-a
fv
de
ipr
fr
pd
pmx
.25L
.5L
A
pn
pn
na
nc
nc
C
nc
nc
D
mx
tr
VSPM
pmx
B
pd
de
qu
a-a

BCAS-A107(2) 45–143 (2008) August 2008

Southern California Academy of Sciences

Founded 6 November 1891, incorporated 17 May 1907

OFFICERS

John Roberts, *President*
Ann Dackey, *Vice-President*
Edith Reed, *Secretary*
Daniel A. Guthrie, *Treasurer*
Daniel A. Guthrie, *Editor*
Brad Blood, *Past President*
Ralph G. Appy, *Past President*
Robert Grove, *Past President*
Daniel J. Pondella, II, *Past President*
John H. Dorsey, *Past President*

BOARD OF DIRECTORS

2005–2008	2006–2009	2007–2009
Jonathan N. Baskin	M. James Allen	Brad R. Blood
John Roberts	Sabrina Drill	Julianne Kalman
Gloria J. Takahashi	Judith Lemus	Jerry Scnubel
Andrea Murray	Darren Sandquist	Kathy Keene
Phillippa Drennan	SusanYoder	Edith Reed

Membership is open to scholars in the fields of natural and social sciences, and to any person interested in the advancement of science. Dues for membership, changes of address, and requests for missing numbers lost in shipment should be addressed to: Southern California Academy of Sciences, the Natural History Museum of Los Angeles County, Exposition Park, Los Angeles, California 90007-4000.

Professional Members	$45.00
Student Members	25.00

Memberships in other categories are available on request.

Fellows: Elected by the Board of Directors for meritorious services.

The Bulletin is published three times each year by the Academy. Manuscripts for publication should be sent to the appropriate editor as explained in "Instructions for Authors" on the inside back cover of each number. All other communications should be addressed to the Southern California Academy of Sciences in care of the Natural History Museum of Los Angeles County, Exposition Park, Los Angeles, California 90007-4000.

Date of this issue 18 July 2008

♾ This paper meets the requirements of ANSI/NISO Z39.48-1992 (Permanence of Paper).

CALIFORNIA
ACADEMY OF SCIENCES
AUG - 6 2008
LIBRARY

Bull. Southern California Acad. Sci.
107(2), 2008, pp. 45–56

A Fossil Skull of the Extant Blue Marlin (*Makaira nigricans* Lacepède, 1802) from the Late Miocene of Orange County, California

Harry L. Fierstine

Biological Sciences Department, California Polytechnic State University, San Luis Obispo, California 93407, hfiersti@calpoly.edu
and Research Associate, Department of Vertebrate Paleontology, Natural History Museum of Los Angeles County, 900 Exposition Boulevard, Los Angeles, California 90007

Abstract.—A nearly complete fossil skull, including the rostrum, of blue marlin, *Makaira nigricans* Lacepède, 1802 (Perciformes: Xiphioidei: Istiophoridae), was collected from the Oso Member (latest Miocene) of the Capistrano Formation, Mission Viejo, Orange County, California. The specimen is compared with extant and fossil istiophorids, and 19 of its 20 morphological variables are within the range of values observed for extant *M. nigricans*, whereas only 13 or less variables are within the observed range of other extant istiophorids. Because extant *M. nigricans* usually inhabits a water column with a height of about 200 m or more and is the most tropical of all xiphioid species, its presence supports the hypotheses that the Oso Member was deposited at upper bathyal depths or greater and that the coastal paleoclimate of southern California was warmer during the late Miocene than at present.

The extant blue marlin, *Makaira nigricans* Lacepède 1802, (Perciformes: Xiphioidei: Istiophoridae) is an important commercial and recreational fish species that inhabits the tropical and temperate Atlantic, Indian, and Pacific oceans, various strata within a water column of about 200 m or more and average sea surface temperatures of approximately 24°C (Nakamura 1985). The blue marlin is rarely observed off the coast of southern California (Eschmeyer et al. 1983).

According to Fierstine (2006), the blue marlin or blue marlin-like xiphioids (*M.* cf. *M. nigricans*) are the most common fossils of the Family Istiophoridae. The earliest records are from the late Miocene where *M. nigricans* was identified in two rock units in southern California, the Monterey and San Mateo formations (Fierstine and Applegate 1968; Fierstine and Welton 1988; Fierstine 1998, 2001), and *M.* cf. *M. nigricans* was identified in three late Miocene rock units, the Eastover Formation, Virginia, U.S.A. (Fierstine 1998), Gatún Formation, Panama (Fierstine 1999), and Pietra leccese, Italy (Carnevale et al. 2002). In addition, blue marlin and blue marlin-like specimens also were described from the Trinidad Formation, Baja California Sur, Mexico, but because the age of the deposit ranges from late Miocene to late Pliocene (Fierstine et al. 2001), the specimens may or may not rank among the earliest known records of *M. nigricans*. The specimens from the two southern California localities were originally identified only to genus (*Makaira* sp.) (Fierstine and Applegate 1968; Fierstine and Welton 1988), but were re-identified by Fierstine (1998, 2001) after more comparative material became available.

In 1980, Hugh Wagner, during a paleomitigation project for the Mission Viejo Company, collected a nearly complete skull of *M. nigricans*, OCPC 31001 (Orange

County Paleontology Collection), from the Oso Member (latest Miocene) of the Capistrano Formation near the current northern city limit of Mission Viejo, Orange County, California (Fig. 1). According to Barnes and Raschke (1991), the Oso Member is correlative with all but the latest Hemphillian North American Land Mammal Age [4.6 to 9.0 Ma (Woodburne and Swisher 1995)]. Although the specimen is the third record of a blue marlin in late Miocene deposits of southern California (Fierstine 2006), it is the only one with a skull and rostrum, and warrants description.

Materials and Methods

Approximately 160 whole and partial skeletons of extant (= Recent or Holocene) specimens, representing seven species of the family Istiophoridae, were examined and used for comparison with the fossil skull. The scientific and common names of Nelson et al. (2004) are used for Recent istiophorids with the exception that I follow Orrell et al. (2006) and place the istiophorids in the suborder Xiphioidei, and Collette et al. (2006) who recognize only one species of blue marlin (*M. nigricans*) instead of two species [*M. nigricans* and *M. mazara* (Jordan and Snyder 1901)]. A combination of the osteological terminology of Arratia (1997), Davie (1990), Gregory and Conrad (1937), Gudger (1940), Rojo (1991), and Schultz (1987) is used.

Anatomical abbreviations are:**a-a**, angular-articular; **bo**, basioccipital; **de**, dentary; **fr**, frontal; **fv**, facet on maxilla for articulation with vomer; **ipr**, internal (anterior) process of the maxilla; **le**, lateral ethmoid; **mpr**, maxillary (posterior) process of the maxilla; **mx**, maxilla(e); **na**, nasal; **nc**, nutrient canal; **pa**, parasphenoid; **pd**, predentary; **pmx**, premaxilla(e); **pn**, prenasal; **pop**, preopercle; **pt**, pterygoid; **qu**, quadrate; **sph**, sphenotic; **tr**, triangular region of maxilla; **vo**, vomer.

Institutional abbreviations are: **LACM**, Natural History Museum of Los Angeles County, Los Angeles, California, U.S.A.; **MAUL**, Museo dell'Ambiente, Lecce University, Puglia, Italy; **OCPC**, Orange County Paleontology Collection, Santa Ana, California, U.S.A.; **UCMP**, University of California Museum of Paleontology, University of California, Berkeley, California, U.S.A.; **USNM**, United States National Museum of Natural History, Smithsonian Institution, Washington, D.C., U.S.A.

Characters and their definition for each bone or structure were taken liberally from Fierstine (1998, 2001) and are as follows:

Rostrum.—Rostra were measured according to the methods of Fierstine and Voigt (1996). Two regions were emphasized: 0.5 L, or one-half the distance between the distal tip and the orbital margin of the lateral ethmoid, and 0.25 L, or one-fourth the distance between the distal tip and the orbital margin of the lateral ethmoid. Cross-sections were obtained at 0.5 L and 0.25 L using computer tomography (CT) at scan values of 120 kv, 100 mA, and 2.0 sec. Characters studied in each region (.05 L and 0.25 L, respectively) were depth (D_1, D_2) and width (W_1, W_2) of the rostrum, height (H_1, H_2) and width (N_1, N_2) of the left nutrient canal (as seen in cross-section), and distance (DD_1, DD_2) of the left nutrient canal from the dorsal surface of the rostrum (as viewed in cross-section). Characters studied without reference to region were distribution of denticles on the dorsal (DZ) and ventral (DVS) surfaces of the rostrum (both measured from the distal tip), length (P) from the distal tip of the rostrum to the distal extremity of the prenasal bone, presence or absence of denticles on the prenasal bone, and length from the tip along the ventral surface where the fused premaxillae divide (VSPM) into separate bones.

Predentary.—Three morphometric characters were studied: length along the ventral mid-line (PL); width across the widest expanse of the toothed surface (PW); and depth

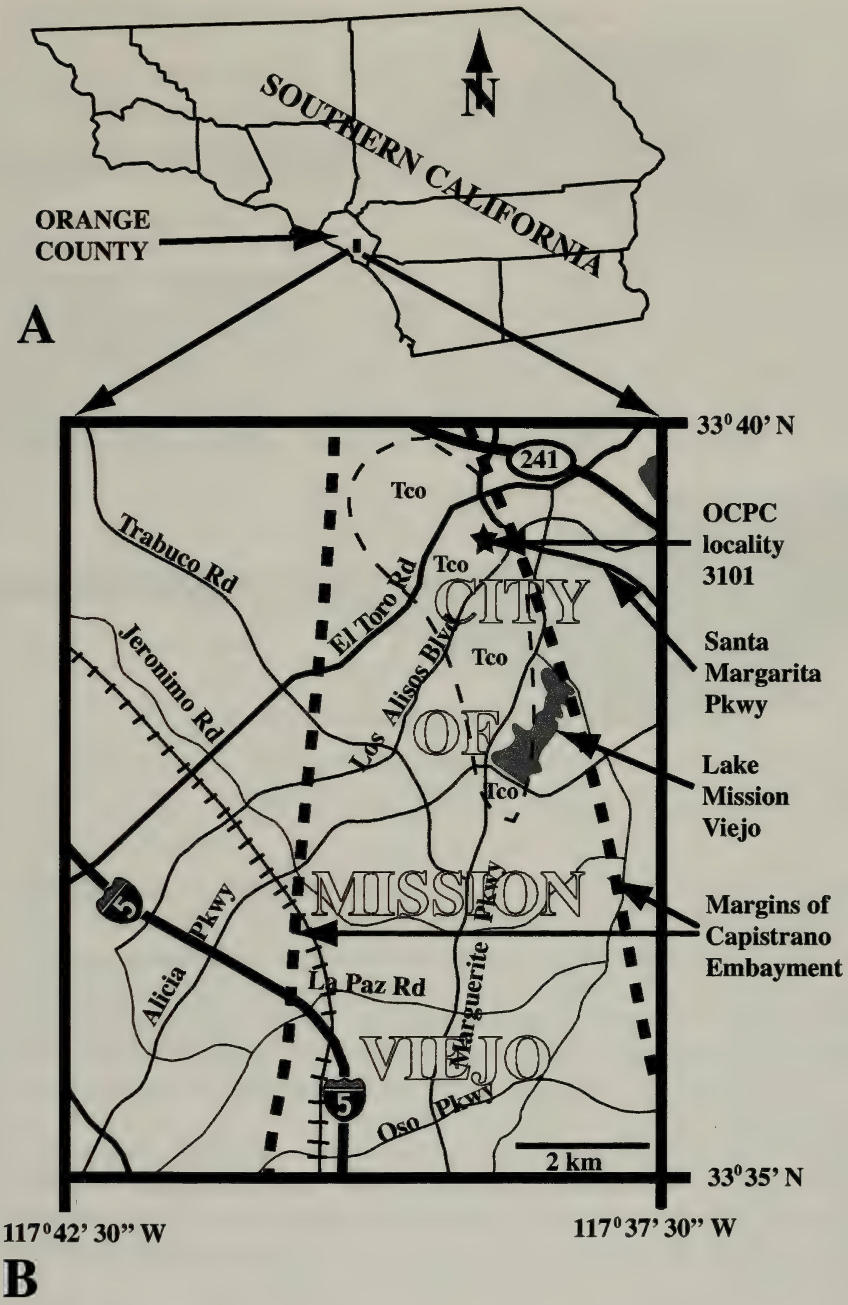

SOUTHERN CALIFORNIA
N
ORANGE COUNTY
A
33° 40' N
241
Tco
OCPC locality 3101
Trabuco Rd
Tco
CITY
El Toro Rd
Santa Margarita Pkwy
Jeronimo Rd
Los Alisos Blvd
Tco
OF
Lake Mission Viejo
Tco
MISSION
5
Margins of Capistrano Embayment
Pkwy
Alicia
La Paz Rd
Marguerite Pkwy
VIEJO
5
Oso Pkwy
2 km
33° 35' N
117° 42' 30" W
117° 37' 30" W
B

Fig. 1. Map of the collection site (OCPC locality 3101) of the skull of *Makaira nigricans* Lacepède 1802 (OCPC 31001), late Miocene, Oso Member, Capistrano Formation. **A**. Orange County in relation to other counties in southern California; **B**. Road map of area around Mission Viejo, Orange County, California with the collection site indicated by a star. Thick dotted lines represent the approximate margins of the northern extension of the Capistrano Embayment and thinner dotted lines within the Capistrano Embayment represent the generalized outcrop of the Oso Member (Tco). [modified from Ehlig (1979) and Morton et al. (2004)].

perpendicular to the long axis from the widest expanse of the toothed surface to the ventral surface of the bone (PD).

Quadrate.—Five characters were measured: greatest height from the condyle for articulation with angulo-articular to the tip of the dorsal process (QH); height from the condyle to the notch for the symplectic bone (QHS); greatest width (medial to lateral) in the region of the condyle (QAW); width of the condyle (QMW); and length of the condyle (QML).

Maxilla.—Six morphometric characters were studied, five in the triangular region (tr) that articulates with the nasal, premaxillae, prenasal, and vomer: length of the triangle (ML), height of the triangle (MH), width from the lateral surface of the triangle to the medial margin of the facet (fv) for articulation with the vomer (MW), and height (MVH) and width (MVW) of the facet. The sixth character is the length of the posterior limb from the anterior tip of the triangle to the posterior tip of the maxillary process (mpr) at the gape (MOL).

Neurocranium.—Because the neurocranium is badly crushed dorso-ventrally, only the presence or absence of its bony constituents is noted.

Systematic Paleontology

Class Actinopterygii Cope 1887

Division Teleostei Müller 1844

Order Perciformes Bleeker 1859

Suborder Xiphioidei Swainson 1839

Family Istiophoridae sensu Robins and de Sylva 1960

Genus *Makaira* Lacepède 1802

Makaira nigricans Lacepède 1802

Figures 2, 3; Tables 1, 2

Material.—OCPC 31001, partial skull, including the skull roof, rostrum, lower jaws and quadrate.

Locality.—OCPC locality 3101 (= MV19), a reddish brown, pebble conglomerate to coarse sand unit of the Oso Member (latest Miocene) of the Capistrano Formation, in a roadcut facing Los Alisos Boulevard approximately 3.5 km northeast of the junction of Los Alisos Boulevard and Trabuco Road, Mission Viejo, Orange County, California, NW 1/4, NE 1/4, Sec. 18, T. 6 S., R. & W., El Toro, California quadrangle, U.S.G.S., 1968 (photorevised 1982), 1:24,000 scale (Fig. 1).

Remarks.—The specimen mostly consists of the rostrum, lower jaws, and a dorso-ventrally crushed neurocranium (Figs. 2,3). The ventral and lateral skull region (basisphenoid, myodome, most of the otic bones and vomer), all the opercular bones (except for part of the preopercule), most of the lateral ethmoids, and suspensoria are missing. Measurements of the specimen are listed in Table 1.

In dorsal view (Figs. 2A, 3A), the distal one half of the rostrum is well preserved, but the proximal half is incomplete and dorso-ventrally compressed (Fig. 2C). Denticles are restricted to the distal 22 mm of the rostrum. The left prenasal (pn) is complete, except for a middle segment, and the right pn is poorly preserved, except for its most distal extension onto the rostrum. The left nasal (na) is more complete than the right na, and its sutures with the frontal (fr) and pn are well-defined. Both fr are preserved. Most of the bones (supraoccipital, epitotic, pterotic, opisthotic, parietal, etc.) that compose the posterior part of the neurocranium are crushed beyond recognition. The right maxilla

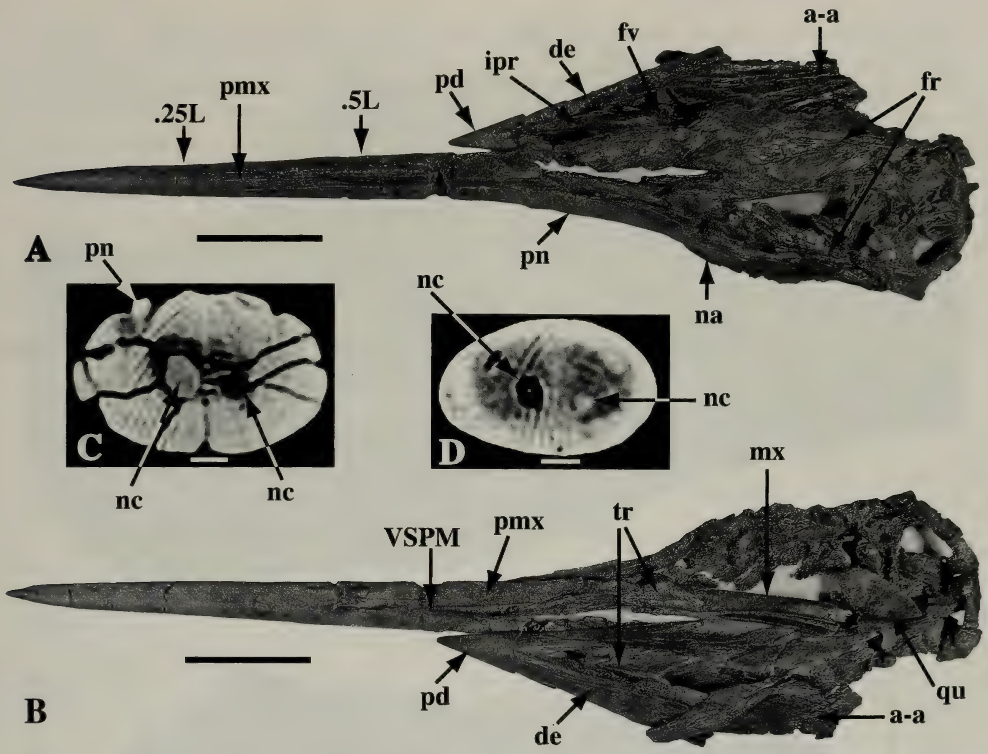


Fig. 2. Skull of *Makaira nigricans* Lacepède 1802 (OCPC 31001), Capistrano Formation, late Miocene, Orange County, California. **A**. Dorsal view; **B**. Ventral view; **C**. Cross section of rostrum at 0.5 L; **D**. Cross section of rostrum at 0.25 L. See text for definition of abbreviations. Scale bar equals 10 cm (A, B) and 5 mm (C, D).

(mx) is better preserved than its counterpart, with the former containing both the articulation for the vomer (fv) and the internal process (ipr). The right dentary (de) is well preserved, except for most of its denticles. The right angulo-articular (a-a) is incomplete posteriorly and is rotated clockwise with respect to the right de.

In ventral view (Figs. 2B, 3B), the distal segment of the rostrum is completely covered with denticles for approximately 261 mm (DZ) and then the denticles divide to form a narrow edentulous zone along the midline that terminates at the division (VSPM) of the right and left maxillae. Most of the right mx, including a large part of the maxillary (posterior) process, is visible. The rugose joint surface on the ventral margins of the left pn and na that articulates with the left mx (triangular region) is well preserved. The interior (ventral) surface of the left fr contains a fragment of the lateral ethmoid (le) and sphenotic (sph). The lateral surface of the left quadrate (qu) is complete; however, the entire element has undergone deformation that gives it a slightly melted appearance. The occipital condyle and ventral surface of the basioccipital (bo) are present. The lower jaw is complete from the distal tip of the predentary (pd) to the posterior part of the de. A small portion of the left a-a and most of the right a-a are visible, and both have been displaced and rotated from their normal anatomical position with respect to their dentaries. A large fragment of the left pterygoid (ecto- and entopterygoid) rests on the right lower jaw. Two flat elements, presumably the ventral surface of the parasphenoid (pa) and a small portion of the vomer (vo), are visible.

In cross section at 0.5 L (Fig. 2C), the rostrum is crushed dorso-ventrally and the exact width and depth of the rostrum were only estimated. The left nutrient canal is abnormally

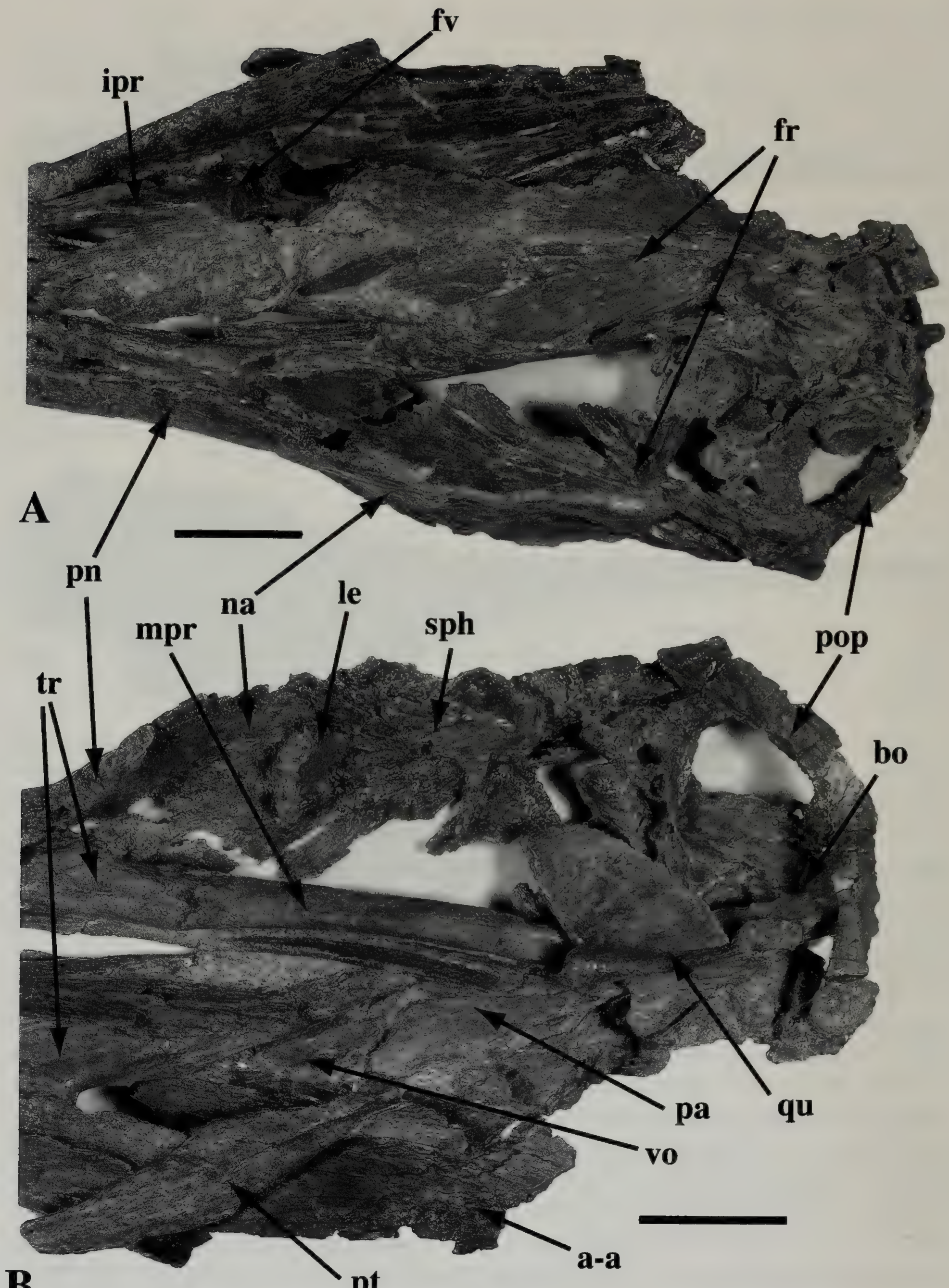

fv
ipr
fr
A
pn
na
le
mpr
sph
pop
tr
bo
pa
qu
vo
a-a
B
pt

Fig. 3. Posterior skull of *Makaira nigricans* Lacepède 1802 (OCPC 31001), Capistrano Formation, late Miocene, Orange County, California. **A**. Dorsal view; **B**. Ventral view. See text for definition of abbreviations. Scale bar equals 5 cm (A, B).

Table 1. Selected measurements of the skull of *Makaira nigricans* Lacepède 1802, OCPC 31001, Oso Member, Capistrano Formation, late Miocene, Orange County, California. See text for definition of abbreviations. Measurements that were distorted during fossilization are given as estimates (est.), and those characters affected by abnormal development of the nutrient canals are noted as questionable (?). Values indicated by an asterisk (*) were taken from computer tomography (CT) scans and not directly from the specimen.

Bone or region of skull	Measurements (mm)
Overall length of specimen	780.0
Rostrum	
Length (L)	570.0
D_1	23.5
W_1	est. 35.1
H_1	?5.7*
N_1	?4.1*
DD_1	?8.7*
IC_1	?2.6*
D_2	17.3
W_2	26.3
H_2	?4.3*
N_2	?2.8*
DD_2	?6.5*
IC_2	–
DZ	22.0
DVS	261.0
P	231.0
VSPM	324.0
Left maxilla	
MH	est. 24.8
ML	51.5
MOL	est. 200.0
MVH	15.5
MVW	14.5
MW	est. 26.5
Left quadrate	
QH	est. 65.7
QHS	est. 52.2
QAW	est. 17.0
QMW	12.0
QML	14.4
QW	74.4
Predentary	
PD	18.2
PL	61.0
PW	30.2

larger than the right, thus the size of the canals (H_1, N_1) and their position with respect to the dorsal surface (DD_1) and to one another (IC_1) were considered too uncertain for comparison with other istiophorids. In cross section at 0.25 L (Fig. 2D), the rostrum is preserved with no evidence of dorso-ventral compression. However, the left nutrient canal is abnormally larger than the right canal also, thus measurements of the size and position of the canals were not used for comparison with other istiophorids.

Table 2. Variables (ratios) of *Makaira nigricans* Lacepède1802, OCPC 31001, Oso Member, Capistrano Formation, late Miocene, California, compared with the mean (x̄), observed range (or), and number of bones examined (n) for the same variables of eight extant species of the family Istiophoridae. Abbreviations for variables are explained in the Materials and Methods section of text. Only variables of normally developed characters (without question marks [?] in Table 1) are listed.

Ratios	OCPC 31001	*I. platypterus* (Shaw and Nodder 1792)	*M. indica* (Cuvier 1832)	*M. nigricans* Lacepède 1802	*T. albidus* Poey 1860	*T. angustirostris* Tanaka 1915	*T. audax* Philippi 1887	*T. pfluegeri* Robins & de Sylva 1963
		x̄ (or) n	x̄ (or) n	x̄ (or) n	x̄ (or) n	x̄ (or) n	x̄ (or) n	x̄ (or) n
Rostrum								
D1/W1	.67	.68(.58–.78)31	.72(.66–.78)10	.70(.59–.80)41	.62(.56–.66)13	.64(.57–.70)3	.68(.59–.80)13	.62(.59–.64)2
D2/W2	.66	.64(.55–.75)30	.68(.58–.77)10	.64(.54–.83)41	.53(.47–.61)14	.61(.58–.64)3	.61(.52–.67)13	.65(.65)2
D2/VSPM	.05	.03(.03–.04)25	.06(0.5–.08)8	.04(.04–.05)35	.04(.03–.05)12	.15(.13–.19)3	.04(.03–.05)12	.05(.05–.06)2
W2/VSPM	.08	.05(.04–.06)24	.09(.07–.10)8	.07(.05–.08)35	.07(.06–.09)12	.24(.20–.30)3	.06(.05–.08)12	.08(.07–.09)2
DVS/VSPM	.81	.72(.48–.97)23	.72(.48–.94)8	.86(.54–1.0)34	.80(.66–.95)9	.31(0–.52)3	.76(.64–.94)10	.02(0–.04)2
P/VSPM	.71	.58(.45–.83)17	.53(.48–.60)8	.51(.38–.87)33	.53(.42–.66)11	.39(.30–.45)3	.48(.38–.57)12	.55(.55–.56)2
P/D2	13.4	18.8(13.0–23.2)18	9.0(7.3–10.5)10	11.9(8.9–20.2)41	14.2(10.9–21.3)12	2.7(2.3–3.3)3	12.9(10.8–16.1)12	10.6(9.8–11.3)2
P/W2	8.8	11.6(8.7–14.0)17	6.1(5.1–7.3)10	7.6(5.9–12.3)41	7.6(5.7–10.3)12	1.6(1.3–2.1)3	7.8(6.7–9.5)11	6.9(6.4–7.4)2
DZ/P	.10	1.4(.76–2.5)18	.30(.10–.50)9	.04(0–.11)37	2.4(1.5–3.3)9	0(0)3	.93(.30–2.0)9	0(0)2
DZ/W2	.84	19.5(9.9–29.1)30	1.8(.71–3.0)9	.30(.00–.85)37	18.6(14.6–21.7)10	0(0)3	5.8(2.5–9.5)11	0(0)2
Maxilla								
ML/MOL	.26	.31(.23–.35)9	—	.20(.17–.23)14	.26(.23–.29)10	—	.26(.25–.27)2	.33(.33–.33)2
MW/MOL	.13	.12(.08–.14)9	—	.13(.13–.13)5	.13(.12–.13)8	—	.12(.12)2	.08(.08–.08)2
MW/ML	.51	.39(.25–.57)14	—	.64(.60–.70)5	.47(.44–.51)8	—	.47(.45–.49)2	.24(.23–.24)2
MH/ML	.48	.33(.26–.47)14	—	.43(.38–.49)14	.38(.34–.45)10	—	.37(.36–.37)2	.33(.31–.34)2
MVW/MVH	.94	1.4(.95–2.4)9	—	1.2(1.1–1.3)3	1.2(.80–1.8)3	—	1.2(.96–1.5)2	—
MVW/ML	.31	.22(.17–.36)9	—	.36(.35–.37)3	.20(.18–.24)3	—	.28(.25–.31)2	—
MVW/MW	.55	.55(.48–.63)9	—	.56(.53–.60)3	.44(.40–.48)3	—	.60(.51–.69)2	—
MVW/MH	.53	.64(.59–.75)9	—	.90(.81–.96)3	.54(.50–.58)3	—	.77(.68–.85)2	—
Predentary								
PW/PL	.50	.50(.23–.63)21	.54(.48–.62)5	.65(.45–1.1)23	.41(.34–.57)15	.60(.54–.69)4	.42(.33–.51)13	(.65)1
PD/PL	.30	.27(.20–.37)21	.38(.30–.41)5	.36(.26–.58)23	.24(.20–.33)15	.59(.52–.69)4	.26(.22–.30)13	(.60)1
PD/PW	.61	.56(.48–1.0)21	.70(.63–.81)5	.56(.48–.61)23	.59(.53–.65)15	.99(.97–1.0)4	.60(.53–.72)13	(.92)1
Quadrate								
QAW/QH	.26	.17(.15–.20)11	.29(.28–.31)2	.23(.19–.27)22	.21(.18–.24)17	(.16)1	.21(.20–.22)4	(.17)1
QMW/QAW	.71	.68(.58–.81)11	.85(.83–.88)2	.77(.57–.92)22	.73(.48–.88)18	(.65)1	.71(.67–.77)4	(.62)1
QAW/QHS	.33	.29(.24–.39)11	.44(.44–.45)2	.36(.30–.43)21	.35(.30–.40)18	—	.38(.37–.39)2	(.30)1
QMW/QHS	.23	.19(.17–.23)11	.38(.38–.38)2	.27(.22–.35)21	.25(.19–.30)18	—	.28(.27–.28)2	(.18)1
QMW/QML	.83	.73(.62–.80)11	1.1(1.1–1.1)2	.86(.63–1.0)22	.83(.53–1.0)18	(.56)1	.79(.65–1.0)4	(.71)1

Discussion and Conclusions

Only 20 of the 26 variables (ratios) listed in Table 2 for OCPC 31001 are considered to have an adequate sample size (n ≥ 7) in three or more species of recent istiophorids to warrant interspecies comparison. Nineteen of the 20 variables are within the range of values observed for *M. nigricans*, with other species having 13 or less variables within their observed range. One variable (ML/MOL) is within the observed range of three extant istiophorids, but not *M. nigricans*. However, the measurement of MOL is an estimate, and perhaps the variable would be within the observed range of *M. nigricans* if it could be more accurately determined. This evidence indicates OCPC 31001 is *M. nigricans*.

With exception of its rostrum, specimen OCPC 31001 has few bones in common with other fossils of the genus *Makaira*. For example, two specimens of *M.* cf. *M. nigricans* (MAUL 917/1; USNM 375733) are the only other *Makaira* with a preserved maxilla (Fierstine 1998; Carnevale et al., 2002) and four specimens of *M.* cf. *M. nigricans* (MAUL 917/1; NCSM 6944; USNM 476372, 481903) are the only other ones with preserved quadrates (Fierstine 2001; Carnevale et al. 2002). Of the 26 variables (ratios) listed in Table 2 for the Capistrano Formation blue marlin, only 22 have been measured in other fossil istiophorids, and, with the exception of specimens from the Yorktown Formation and Pietra leccese, measurements were recorded from a single bone or structure that represents a single individual. It is not surprising then that only 14 variables of the Capistrano marlin are close to (± 25%) or within the observed range of other fossil istiophorids.

Paleoenvironment

The depth of deposition of the Oso Member has only been described in general terms. Based primarily on the stratigraphy of Vedder (1972), Barnes and Raschke (1991) interpreted the Oso Member as a nearshore (proximal) facies of the Capistrano Formation that has yielded remains of land mammals. Deméré and Berta (2005), based on the biostratigraphy of White (1956) and Ingle (1979), interpreted the Oso Member as probably being deposited at continental shelf depths (i.e., somewhere between 0 and 200 m). Ehlig (1979) concluded that the Oso Member in the northeastern part of the Capistrano Embayment (Fig. 1) was deposited at upper bathyal depths (i.e., 200 m or greater). Because all three studies differ in their interpretation of the depth of the deposit, perhaps the billfish skull can provide more precise bathymetric evidence for the Oso Member in the northeastern portion of the embayment.

Recent blue marlins are oceanic fishes (i.e. favor inhabiting a water column with a height greater than 200 m) and are rarely encountered in shallow, nearshore waters. They are not seen near landmasses or islands unless they are in the vicinity of a deep drop-off from the continental shelf (Nakamura 1985). If it is assumed that fossil istiophorids had ecological preferences similar to extant istiophorids (Fierstine 1998, 2001, 2006), then the presence of blue marlin remains in the Oso Member suggests that the stratum was deposited in at least 200 m of water. Unlike the carcasses of large marine mammals that often float after death and sometimes end up in more inshore waters (Berta et al. 2006), the carcasses of xiphioid fishes usually sink, based on pop-up satellite archival tags released from dead fish (E. Prince, NOAA, Miami, FL, pers. comm., October 29, 2007). Because the fossil skull (OCPC 31001) is fairly complete and shows no wear or breakage (e.g., the rostrum is articulated with the neurocranium), it is unlikely it was transported by ocean currents or wave action. Therefore, the billfish probably died in the vicinity of the water column where its skull became entombed.

Blue marlins inhabit temperate and tropical waters of the Atlantic and Indo-Pacific Oceans and are considered the most tropical of all istiophorid species (Nakamura 1983). They are generally found in water with an average sea surface temperature of approximately 24°C. As noted above, extant blue marlins are occasionally found off southern California (Eschmeyer et al. 1983), but only during periods of anomalously high sea surface temperatures (The Southwest Fisheries Science Center's 1996 Billfish Newsletter [unpublished]). Thus, the presence of *M. nigricans* in the Capistrano Formation offers further support that the coastal paleoclimate of southern California was warmer during the late Miocene than at present (Fierstine 2006).

Acknowledgments

I want to thank H. Wagner (SDNHM) for his collecting expertise, and allowing me to prepare and study the fossil marlin. J. Cooper (OCPC) and L. Babilonia (Los Coyotes Paleontology Museum) encouraged study of the specimen. J. Cooper (OCPC) and G. Takeuchi (LACM) generously provided pertinent literature and critically read various drafts of the manuscript. T. Deméré (San Diego Natural History Museum) furnished thoughtful criticisms of the submitted manuscript, and E. Prince (NOAA, Miami, FL) provided important literature and shared his extensive knowledge of tagging studies in billfishes.

Literature Cited

Arratia, G. 1997. Basal teleosts and teleostean phylogeny. Palaeo Ichthyologica, 7:5–158.

Barnes, L.G. and R.E. Raschke. 1991. *Gomphotaria pugnax*, a new genus and species of Late Miocene dusignathine otariid pinniped (Mammalia: Carnivora) from California. Contributions in Science, Natural History Museum of Los Angeles County, (426): 1–16.

Berta, A., J.L. Sumich, and K.M. Kovacs. 2006. Marine mammals: Evolutionary biology. 2nd ed. Elsevier/Academic Press, San Diego, California, U.S.A. 547 pp.

Bleeker, P.E. 1859. Enumerato Specierum Piscium hucusque in Archipelago Indico obervataum. Verhandelingen der Natuurkundige Vereeniging in Nederlandsch Indië, 6:1–276.

Carnevale, G., C. Sorbini, W. Landini, and A. Varola. 2002. *Makaira* cf. *M. nigricans* Lacepède, 1802 (Teleostei: Perciformes: Istiophoridae) from the Pietra Leccese, Late Miocene, Apulia, Southern Italy. Palaeontographia Italica, 88:63–75.

Collette, B.B., J.R. McDowell, and J.E. Graves. 2006. Phylogeny of recent billfishes (Xiphioidei). Bull. Mar. Sci., 79(3): 455–468.

Cope, E.D. 1887. Geology and paleontology. Amer. Naturalist, 21:1014–1019.

Cuvier, G. 1832. *Tetrapturus indicus*, Pp. 554–626 *in* G. Cuvier and A. Valenciennes. Histoire Naturelle Poissons, volume 8 (9, Des Scombéroides). F.G. Levrault, Paris. 509 pp.

Davie, P. 1990. Pacific marlins: anatomy and physiology. Massey Univ. Press, Palmerston North, New Zealand. vii + 88 pp.

Deméré, T.A. and A. Berta. 2005. New skeletal material of *Thalassoleon* (Otaridae: Pinnipedia) from the Late Miocene-Early Pliocene (Hemphillian) of California. Bull. Fla. Mus. Nat. Hist., 45(4): 379–411.

Ehlig, P. 1979. The late Cenozoic evolution of the Capistrano Embayment. Pp. A38–A46 *in* (D.L. Fife ed.), Geologic Guide of San Onofre Nuclear Generating Station and Adjacent Regions of Southern California. Pacific Sections of AAPG, SEPM, and SEG, Guidebook 46.

Eschmeyer, W.N., E.S. Herald, and H. Hammann. 1983. A field guide to Pacific Coast fishes of North America. The Peterson Field Guide Series. Houghton Mifflin Company, Boston, Massachusetts, U.S.A. 336 pp.

Fierstine, H.L. 1998. *Makaira* sp., cf. *M. nigricans* Lacépède, 1802 (Teleostei: Perciformes: Istiophoridae) from the Eastover Formation, late Miocene, Virginia, and a reexamination *Istiophorus calvertensis* Berry, 1917. J. Vert. Paleo., 18:30–42.

———. 1999. *Makaira* sp., cf. *M. nigricans* Lacépède, 1802 (Teleostei: Perciformes: Istiophoridae) from the Late Miocene, Panama, and its probable use of the Panama Seaway. J. Vert. Paleo., 19(3): 430–437.

———. 2001. Analysis and new records of billfish (Teleostei: Perciformes: Istiophoridae) from the Yorktown Formation, Early Pliocene of eastern North Carolina at Lee Creek Mine. Pp. 21–69 *in* (C.E. Ray, and D.J. Bohaska, eds.), 2001. Geology and Paleontology of the Lee Creek Mine, North Carolina, III. Smithsonian Contributions to Paleobiology, no. 90.

———. 2006. Fossil history of billfishes (Xiphioidei). Bull. Mar. Sci., 79(3): 433–453.

——— and S.P. Applegate. 1968. Billfish remains from southern California with remarks on the importance of the predentary bone. Bull. South. Calif. Acad. Sci., 67(1): 29–39.

——— and N. Voigt. 1996. Use of rostral characters for identifying adult billfishes (Teleostei: Perciformes: Istiophoridae and Xiphiidae). Copeia, 1996(1): 148–161.

——— and B.J. Welton. 1988. A late Miocene marlin, *Makaira* sp. (Perciformes, Osteichthyes) from San Diego County, California, U.S.A. Tertiary Research, 10(1): 13–19.

———, S.P. Applegate, G. González-Barba, T. Schwennicke, and L. Espinosa-Arrubarrena. 2001. A fossil blue marlin (*Makaira nigricans* Lacépède) from the middle facies of the Trinidad Formation, (Upper Miocene to Upper Pliocene), San José del Cabo Basin, Baja California Sur, México. Bull. South. Calif. Acad. Sci., 100(2): 59–73.

Gregory, W.K. and G.M. Conrad. 1937. The comparative osteology of the swordfish (*Xiphias*) and the sailfish (*Istiophorus*). Amer. Mus. Novitates, 952:1–25.

Gudger, E.W. 1940. The alleged pugnacity of the swordfish and the Spearfishes as shown by their attacks on vessels. Mem. Royal Asiat. Soc. Bengal, 12:215–315 + 9 pls.

Ingle, Jr., J.C. 1979. Biostratigraphy and paleoecology of early Miocene through early Pleistocene benthonic and planktonic Foraminifera, San Joaquin Hills-Newport Bay-Dana Point area, Orange County,California. Pp. 53–77 *in* (C.J. Stuart ed.), Miocene Lithofacies and Depositional Environments, Coastal southern California and Northwestern Baja California. Pacific Section SEPM.

Jordan, D.S. and J.O. Snyder. 1901. Description of nine new species of fishes contained in museums of Japan. J. Coll. Sci., Imp. Univ. Tokyo, 33:1–497.

Lacepède, B.G.E. 1802. Histoire naturelle des poissons. 4:689–697.

Morton, D.M. (compiler), K.R. Bovard, and R.M. Alvarez. 2004. Preliminary digital geologic map of the Santa Ana 30-minute X 60-minute quadrangle, Southern California, scale 1:100,000; U.S. Geological Survey Open-File Report, 99-172, version 2.0.

Müller, J. 1844. Über den Bau und die Grenzen der Ganoiden, und über das natürliche System der Fische. Physikalich-Mathematische Abhandlungen der köninglichen Akademie der Wissenschaften zu Berlin, 1845:117–216.

Nakamura, I. 1983. Systematics of billfishes (Xiphiidae and Istiophoridae). Publ. Seto Mar. Biol Lab., 28: 255–396.

———. 1985. An annotated and illustrated catalogue of marlins, sailfishes, spearfishes, and swordfishes known to date. Food and Agricultural Organization of the United Nations (FAO) Fisheries Synopsis, 125(5): 1–65.

Nelson, J.S., E.J. Crossman, H. Espinosa-Pérez, L.T. Findley, C.R. Gilbert, R.N. Lea, and J.D. Williams. 2004. Common and Scientific Names of Fishes from the United States, Canada, and Mexico. 6th ed., Amer. Fish. Soc. Spec. Publ. 29, 386 pp.

Orrell, T.M., B.B. Collette, and G.D. Johnson. 2006. Molecular data support separate Scombroid and xiphioid clades. Bull. Mar. Sci, 79(3): 505–519.

Philippi, R.A. 1887. Sobre los tiburones y algunos otros peces de Chile. Annales del Universidad de Chile, 71:535–574.

Poey, F. 1860. Memorias sobre la historia de la Isla de Cuba, acompañdas de sumarios latinos y extractos in francés etc., volume 2, Pp. 97–336. La Habana.

Robins, C.R. and D.P. deSylva. 1960. Descriptions and relationships of the longbill spearfish, *Tetrapturus belone*, based on western north Atlantic specimens. Bull. Mar. Sci. of the Gulf and Caribbean, 10(4): 383–413.

——— and ———. 1963. A new Western Atlantic spearfish, *Tetrapturus pfluegeri*, with a redescription of the Mediterranean Spearfish, *Tetrapturus belone*. Bull. Mar. Sci. of the Gulf and Caribbean, 13(1): 84–122.

Rojo, A.L. 1991. Dictionary of evolutionary fish osteology. CRC Press, Boca Raton, Florida. 273 pp.

Schultz, O. 1987. Taxonomische Neugruppieriung der Überfamilie Xiphioidea (Pisces, Osteichthyes). Annalen Naturhistorisches Museum Wien, Serie A, für Mineralogie und Petrographie, Geologie und Paläontologie, Anthropologie, und Prähistories, 89:95–202.

Shaw, G. and F.P. Nodder. 1792. *Xiphias platypterus*: the broadfinned swordfish. The Naturalist's Miscellany, 28:pages unnumbered, plate 88 pp.

Swainson, W. 1839. The natural history and classification of fishes, amphibians, and reptiles, or monocardian animals 2. Longman, Orme, Green and Longmans & John Taylor, London. 448 pp.

Tanaka, S. 1915. Figures and descriptions of the fishes of Japan including Riuku Islands, Bonin Islands, Formosa, Kurile Islands, Korea and southern Sakhalin, 19:319–342, Daiichi Shoin, Tokyo.

Vedder, J.G. 1972. Review of stratigraphic names and megafaunal correlation of Pliocene rocks along the southeast margin of the Los Angeles basin, California. Pp. 158–172 *in* (E.H. Stinemeyer, ed.). Pacific Coast Miocene Biostratigraphic Symposium. SEPM.

White, W.R. 1956. Pliocene and Miocene Foraminifera from the Capistrano Formation, Orange County, California. J. Paleo. 30:237–260.

Woodburne, M.O. and C.C. Swisher, III. 1995. Land mammal high-resolution geochronology, intercontinental overland dispersals, sea level, climate, and vicariance. Pp. 335–364 *in* (W.A. Berggren, D.V. Kent, M.-P. Aubry, and J. Hardenbol, eds.), Geochronolgy, Time Scales and Global Stratigraphic Correlation. Soc. Sed. Geol., Spec. Publ. 54.

Accepted for publication 12 October 2007.

Bull. Southern California Acad. Sci.
107(2), 2008, pp. 57–67

An Initial Carnivore Survey of Griffith Park, Los Angeles, California

Paul D. Mathewson,[1]*† Stephanie N. Spehar,[1]# and Daniel S. Cooper[2]

[1] *1625 Grandview Ave., Glendale, CA 91201*
[2] *Cooper Ecological Monitoring, Inc., 5850 W. 3rd St., #167, Los Angeles, CA, 90036*

Abstract.—We established 42 carnivore detection stations in Griffith Park, Los Angeles, CA, in June 2007 to gather baseline information about wildlife species in the park. We documented the widespread presence of coyotes (*Canis latrans*), striped skunks (*Mephitis mephitis*), and raccoons (*Procyon lotor*), and the localized presence of bobcats (*Lynx rufus*), gray foxes (*Urocyon cinereoargenteus*), and Virginia opossums (*Didelphis virginiana*). Carnivore diversity and detection rates were greatest at the park's borders and along wooded canyons. Our data suggest a possible avoidance of areas heavily used by hikers and dogs, despite the presence of suitable habitat. This represents Griffith Park's first formal mammal survey.

Introduction

Griffith Park, at 1,700 ha the nation's largest municipally-owned park, is a natural oasis for both human and wildlife populations of Los Angeles. Despite being surrounded by urban development, Griffith Park has remained in large part a natural environment. The park lies within the California Floristic Province, a biome considered one of 34 biodiversity hotspots for conservation worldwide due to its high levels of diversity, endemism, and the degree to which it is threatened (Myers et al. 2000). Griffith Park itself has become increasingly isolated from other nearby open areas and their extensive wildlife habitat due to development. Two major roadways (US 101 and Interstate 405) separate the park from the rest of the Santa Monica Mountains and its large areas of protected and undeveloped land, which include the Santa Monica Mountains National Recreation Area (the eastern-most arm of which extends to ~3 km west of the park) and several state parks. Griffith Park is also separated from the Verdugo (~5 km to the north) and San Gabriel Mountains (~10 km to the northeast) by continuous residential and commercial development. In spite of its location within this highly urbanized landscape, there are frequent wildlife sightings and reports from the park that indicate permanent habitation within the park by at least some large mammal species. However, to date, no formal studies of wildlife presence and/or distribution have been conducted, inhibiting proper management of the park's natural resources.

Carnivores are good indicators of the park's overall ecological health as their survival is contingent upon diverse and reliable food sources. Given their low densities and large home ranges, they may also be considered "umbrella" species, as management and conservation efforts targeted at carnivores also encompass many other species (Fleish-

---

* Current address: 558a Monroe St., Oshkosh, WI 54901.

† Corresponding author: paul.mathewson@gmail.com

# Current Address: University of Wisconsin-Oshkosh, Department of Religious Studies and Anthropology, 800 Algoma Blvd., Oshkosh, WI 54901.

man et al. 2001). We focused on mid-sized carnivores, or mesocarnivores, for this study. These species have a much more generalized ecology than their larger counterparts and are less likely to be extirpated from areas of high human density and fragmentation (Parks & Harcourt 2002, Crooks 2002).

This study presents the first survey of Griffith Park's mammals. We established 42 tracking stations at seven sampling areas June 2007 and quantified detection frequency, species richness and species diversity of seven target species. We also gathered preliminary data on the effects of habitat type and human disturbance in limiting carnivore distribution in the park. The target species included all of the large and mid-sized carnivores that have been reported in the park, including mountain lions (*Puma concolor*), coyotes (*Canis latrans*), bobcats (*Lynx rufus*), gray foxes (*Urocyon cinereoargenteus*), raccoons (*Procyon lotor*), and striped skunks (*Mephitis mephitis*). The Virginia opossum (*Didelphis virginiana*) is also included as a target species because its generalist ecology is similar to that of mesocarnivores, and it can be detected by the same methods employed to detect carnivores in this study (e.g. Boydston 2004). In addition to the target species, other mammalian carnivores possibly present in the park [e.g., long-tailed weasels (*Mustela frenata*)] would also likely be detected by these methods.

Methods

Study area

Griffith Park is located entirely within the city of Los Angeles. It is situated on the eastern end of the Santa Monica Mountains, and elevations within the park range from just over 100 m along the Los Angeles River to more than 500 m above sea level along the highest ridges. An ecologically similar area of undeveloped, privately-owned land abuts the northwestern portion of the park, and Forest Lawn Cemetery adjoins the park's northern border. The rest of the park is separated from other nearby open areas by dense urban development. The average housing unit density to the west towards open space in the Santa Monica Mountains is nearly 1000 houses per square mile, and the density north, east and south of the park exceed 3000 houses per square mile (U.S. Census 2000). Though Griffith Park contains several golf courses and museums, an observatory, a zoo, and numerous picnic areas and playing fields, its rugged interior has remained largely undeveloped aside for a network of trails and fire roads. The natural landscape consists of native vegetation types (mixed chaparral, mixed scrub, oak-sycamore riparian, oak woodland and walnut woodland) and areas of introduced or altered vegetation (including pine and eucalyptus plantations), the latter particularly in the eastern portion of the park (Meléndrez 2004) (Fig. 1). A wildfire in May 2007 burned approximately 20% of the park at its southeastern corner.

Detection stations

We assembled and monitored 42 carnivore detection stations from June 6–24, 2007. These detection stations were placed along sampling lines, which consisted of 3–10 stations set at least 150 meters apart along existing access roads and hiking trails. These sampling lines were set up in seven areas of the park representing a cross-section of the habitat types found in the park. Sampling lines included both burned and unburned sites (Fig. 1).

In each sampling line we alternated between tracking stations and experimental hair snares. Tracking stations consisted of powdered gypsum spread smoothly in a 1.5 m diameter circle that had been cleared of vegetation. Several drops of a commercial

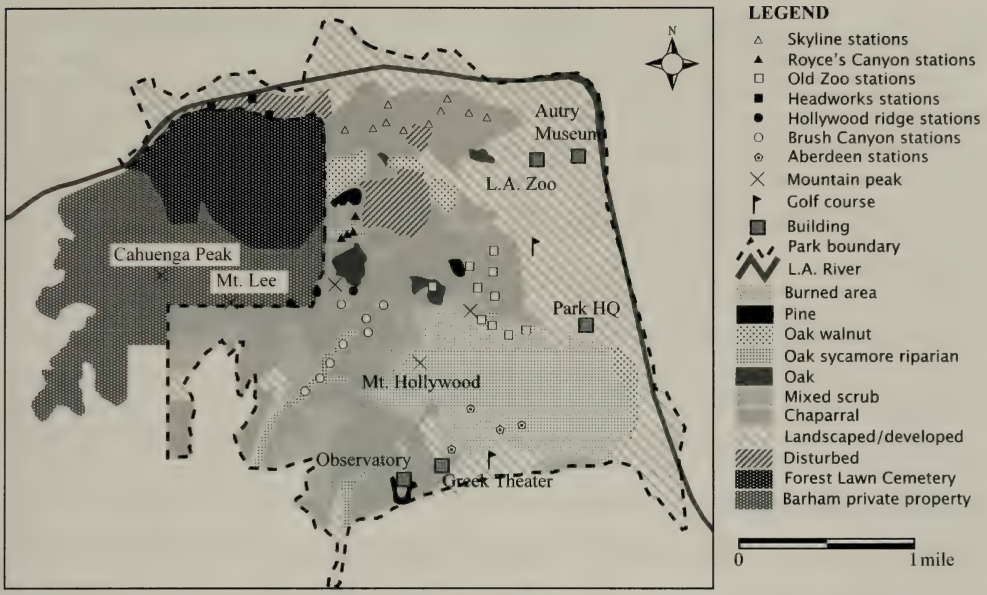

N
Autry Museum
L.A. Zoo
Cahuenga Peak
Mt. Lee
Park HQ
Mt. Hollywood
Observatory
Greek Theater
LEGEND
△ Skyline stations
▲ Royce's Canyon stations
□ Old Zoo stations
■ Headworks stations
● Hollywood ridge stations
○ Brush Canyon stations
⊙ Aberdeen stations
× Mountain peak
Golf course
Building
Park boundary
L.A. River
Burned area
Pine
Oak walnut
Oak sycamore riparian
Oak
Mixed scrub
Chaparral
Landscaped/developed
Disturbed
Forest Lawn Cemetery
Barham private property
0
1 mile

Fig. 1. Vegetation types in Griffith Park, Los Angeles, CA., with locations of carnivore detection stations. Vegetation types were based on Melendrez (2004) and drawn from digital orthoquadrant images without a formal ground-truthing effort. All boundaries should be considered approximate.

trapping lure (Gusto, Minnesota Trapline Products, Pennock, MN) were placed in the center of the circle to entice animals to enter the station and leave tracks. This lure has proven effective in attracting numerous carnivore species (e.g., Long et al. 2007). Reflective aluminum takeout containers and carpet squares scented with trapping lure were hung with fishing line nearby to further attract target species (following McDaniel et al. 2000).

Hair snare station design followed Harrison (2006) and consisted of a 10 cm by 10 cm square of commercial carpeting with 12 10 mm-long staples driven through the back. The carpet squares were scented with approximately 15 ml of trapping lure with several drops of imitation catnip oil and sprinkled with crushed dried catnip and placed approximately 40 cm off the ground. A 0.8 m radius semicircle of ground at the base of the snares was cleared and tracking substrate was spread. The hair snares were employed as an experimental test method for use in future studies that would require individual animal identification through genetic markers found in hair samples. All species identifications from hair snare stations for this study were made from tracks found at the base of the snares.

All animal sign present in the immediate vicinity of each station was noted during assembly to ensure that subsequent detections during the study were new. Stations were checked each day for the first four days, and every other day for the following eight days (Schauster et al. 2002, Gese et al. 2004, Manley et al. 2005). All identifiable tracks were measured, noted, and photographed, and new scat and other animal sign in the vicinity of the stations were recorded. After each examination, the tracking substrate was smoothed, and additional substrate and lure were added as necessary. Heavy machinery work and access restrictions prohibited us from visiting stations at one site (Aberdeen) on the second day of monitoring; those stations were monitored for an additional day. The sampling line along Hollywood Ridge was set up one day late, and was thus monitored for only 11 days; stations in the Headworks area were only monitored for four continuous days (following Gese et al. 2004).

It was at times difficult to distinguish between the tracks of domestic dogs and coyotes in areas where both were present. We assumed all ambiguous tracks were coyote only if we were also able to ascertain coyote presence at that station through other detection means such as scat, urination, or hair rubs. If we could not confirm coyote presence through other sign, ambiguous tracks were omitted from the dataset.

Data analysis

Absolute population numbers cannot be ascertained from tracking stations, as we cannot identify individual tracks and there is no way to distinguish tracks of a repeat visitor to a station from multiple visitors. Instead, we used a relative detection index for each target species as a means of analysis. The detection index (DI) for a given species (*i*) was calculated by dividing the total number of times a species was detected at any station (d_i) by the total sampling effort. The total sampling effort was calculated by summing the number of nights each station (*j*) was operating:

$$DI_i = d_i \Big/ \sum (\text{station}_j \times \text{days operated})$$

The detection index ranged from 0 (species not found at any station) to 1 (species found at every station every night), and can be used to compare the ease with which different species are detected; from this, relative abundance can be inferred (Crooks 2002). Similar calculations can be made when grouping stations by sampling area to compare relative abundance in different areas of the park.

In order to quantify target species biodiversity more completely than simply looking at species richness, we used the Shannon diversity index. This index takes into account the relative abundance of species within a sample, as well as how evenly species are distributed within that sample. It is not affected by sample size, allowing comparison across unequally sampled areas. The Shannon diversity index (H) is calculated by taking the proportion of a given species (*i*) out of all species present and multiplying it by the natural log of this proportion. This is done for all species in the sample, and the products are summed and multiplied by -1. Greater H values indicate a higher level of species diversity:

$$H = -\sum (p_i \times \ln(p_i))$$

A species evenness value, which measures how evenly study species are distributed in a given area, can then be calculated. The Shannon index (H) is divided by the log of the total number of species in the sample (S):

$$E_H = H/\log(S)$$

Evenness (E_H) approaches 0 as a sample becomes dominated by a single species and approaches 1 as a sample has similar proportions of all species.

Results

The 42 detection stations were monitored for a total survey effort of 491 nights. We detected six of seven target species; only mountain lion presence could not be confirmed. Coyotes were the most easily detected and widespread species, its tracks accounting for nearly 80% of all carnivore tracks detected (Table 1). Coyotes had the highest detection

Table 1. Number of mammal species detections at all stations. The shaded rows indicate stations with hair snares.

Station	Coyote	Fox	Bobcat	Raccoon	Skunk	Opossum	Deer[1]	Rabbit[1]	Domestic Dog[2]
Skyline 1	7	—	—	1	1	—	—	1	X
2	1	—	1	1	—	1	—	—	X
3	8	—	—	1	—	—	—	—	X
4	—	—	—	—	—	—	1	—	—
5	5	—	—	—	—	—	—	—	
6	8	—	—	—	—	1	—	—	X
7	6	—	—	—	—	—	—	—	—
8	3	—	—	1	1	—	1	—	—
9	1	—	—	—	—	—	—	—	—
10	6	—	—	1	2	—	3	1	X
Brush 1	—	—	—	—	—	—	—	—	—
2	4	—	—	—	—	—	—	—	X
3	5	—	—	—	—	—	—	—	X
4	8	—	—	—	—	—	—	2	—
5	4	—	—	—	—	—	—	1	—
6	3	—	—	—	—	—	—	—	X
7	7	—	—	—	—	—	—	—	X
8	7	—	—	1	1	—	1	2	—
Royce 1	4	—	1	1	—	—	—	—	—
2	4	—	—	2	—	—	1	—	—
3	3	—	2	—	—	—	1	—	—
4	—	—	—	—	—	—	2	—	—
Old Zoo 1	7	—	—	—	2	—	1	1	—
2	1	—	—	—	—	—	2	—	—
3	3	—	1	—	1	—	1	2	—
4	4	1	1	1	2	—	—	—	—
5	7	—	—	—	2	—	3	3	—
6	8	1	1	—	2	—	—	1	—
7	5	—	—	1	—	—	—	—	—
8	4	—	—	2	1	—	2	—	—
9	8	2	—	1	—	—	2	—	X
10	2	—	—	—	1	—	—	—	—
Aberdeen 1	5	—	—	—	—	—	4	—	X
2	4	—	—	1	—	—	—	—	—
3	5	—	—	—	—	—	—	2	X
4	5	—	—	—	—	—	—	—	X
Hollywood 1	6	—	—	—	—	—	3	1	X
2	2	—	—	—	—	—	1	—	—
3	5	—	1	—	—	—	—	—	X
Headworks 1	1	—	—	—	1	—	—	1	X
2	1	—	—	3	—	—	—	3	—
3	1	—	—	—	—	—	1	1	—
Total	**178**	**4**	**8**	**18**	**17**	**2**	**30**	**22**	**N/A**

[1] *Odocoileus hemionus* and *Sylvilagus* spp.; nontarget wildlife species. These are likely coincidental detections and are not used in analyses.

[2] *Canis familiaris* tracks detected at scent stations. Only presence/absence recorded; an "X" indicates presence. Data not used in analyses.

Table 2. Detection indices for mammalian carnivore species in different sample areas.

	Coyote	Fox	Bobcat	Raccoon	Skunk	Opossum
Skyline	0.375	—	0.008	0.042	0.033	0.017
Brush	0.396	—	—	0.010	0.010	—
Royce	0.229	—	0.063	0.063	—	—
Old Zoo	0.377	0.031	0.023	0.038	0.085	—
Aberdeen	0.365	—	—	0.019	—	—
Hollywood	0.394	—	0.030	—	—	—
Headworks	0.250	—	—	0.250	0.083	—
Total	**0.363**	**0.008**	**0.016**	**0.037**	**0.035**	**0.004**

index of all target species; its presence was identified in all seven sample areas and at all but three detection stations.

Raccoons were detected at six of the seven sample areas, and both striped skunks and bobcats were found in four of the seven areas each, with skunks detected at nearly twice as many stations as bobcats and at a much higher detection index (Table 2). Opossums and gray foxes had the lowest detection index of the target species; both were only detected in a single area each (Table 2).

A maximum of five carnivore species was detected at two survey areas (Skyline and Old Zoo); the Aberdeen area exhibited the lowest species richness with only two target species detected (Table 3). When carnivore diversity was calculated using the Shannon diversity index, Old Zoo also had the highest diversity level (Table 3). While Royce Canyon and Brush Canyon had the same species richness (n=3), Royce Canyon had a much higher diversity index; only one station in Brush Canyon detected any carnivore species other than the coyote (Tables 1 and 3).

Because of the recent fire, only certain trails in the park were open to the general public at the time of the study. Three sample areas, Skyline, Brush Canyon, and Hollywood Ridge, coincided with areas of high human usage. We grouped stations by (subjective) levels of human use, and present detection rates for each target species in each group. While the same number of carnivore species were detected in both groups, stations in areas of high human use recorded a significantly lower level of carnivore diversity (Mann-Whitney U test, U=119, p=0.047), about half that of areas where humans were excluded (Table 3).

Table 3. Carnivore richness, diversity, and evenness in different sample areas in Griffith Park, Los Angeles, CA.

Area (#stations)	Species Richness	Shannon Index (H)	Evenness (E_H)
Skyline (10)	5	0.78	0.16
Brush (8)	3	0.23	0.05
Royce (4)	3	0.89	0.18
Old Zoo (10)	5	1.03	0.21
Aberdeen (4)	2	0.20	0.04
Hollywood (3)	2	0.26	0.05
Headworks (3)	3	1.00	0.20
Total (42)	**6**	**0.82**	**0.14**
High Human Use (21)	5	0.57	0.11
Low Human Use (21)	5	0.98	0.20
Ridgetops (14)	4	0.42	0.10
Lower Altitude (28)	6	0.97	0.16

The distribution of vegetation types in Griffith Park was found to coincide with elevation, with wooded habitats (e.g., oak-sycamore riparian, oak woodland) typically found below 300 m (particularly along canyon bottoms), and scrub and chaparral habitats above 300 m, including along the higher ridges. Because several habitat types were sampled at a very small number of stations, we divided the stations into two groups by elevation for a preliminary habitat analysis. Low-elevation stations recorded significantly higher levels of species diversity (Mann-Whitney U test, $U=99$, $p=0.026$; Table 3), and the coyote was the only carnivore species detected on more than one occasion at high-elevation stations.

To assess potential effects of the recent wildfire, one may compare results from the one sample area located entirely within the burn zone (Aberdeen) with the others. Three stations in the Old Zoo sample area were also set in a burned area, but were adjacent to unburned habitat (Fig. 1). Aberdeen had the lowest carnivore detection rate, carnivore species richness, and species diversity of all areas sampled. With the exception of a single raccoon, all carnivore detections at Aberdeen were of coyotes. The Old Zoo stations set at the edge of the burned area had much higher detection rates, species richness, and diversity than the Aberdeen stations (Tables 1 and 3).

Discussion

Coyotes

Coyotes appear to be the most abundant and widespread carnivore in the park, found in all sample areas at similar detection rates. Previous studies have demonstrated that coyote home range size is quite elastic and highly variable depending on food abundance and degree of surrounding development (Gehrt 2004). A study of coyote home range size in and around the Santa Monica Mountains National Recreation Area immediately west of Griffith Park found that home range size varied between 125 ha to 324 ha (Tigas et al. 2002). Given home ranges of similar size, the park could support around ten pairs of coyotes, assuming overlapping territories of the males and females of a pair. It is also likely that additional coyotes residing in the surrounding urban areas regularly visit the park, augmenting park numbers. Feeding of coyotes by park visitors and nearby residents is a frequently encountered problem (G. Randall, City of Los Angeles, pers. comm.).

Bobcats

Bobcats were found in four areas within the park; two of these areas see high levels of human use (Hollywood Ridge and Skyline), but the area that had by far the highest detection index—Royce Canyon (tracks noted on four separate occasions)—sees low levels of human activity. Previous bobcat studies in southern California have found both spatial and temporal displacement of bobcats in response to high levels of human activity (Tigas et al. 2002, George and Crooks 2006). Tigas et al. (*Ibid*) reports mean home range sizes of 149.8 and 125.2 ha for male and female bobcats, respectively, in unfragmented southern California habitat, and reported that home range size did not increase with fragmentation. This suggests that Griffith Park is large enough to support as many bobcat pairs as coyote pairs; however, the distribution of this species may be limited by human disturbance, particularly along canyon bottoms popular with hikers (e.g., Brush Canyon).

Raccoons and striped skunks

We found that raccoons and striped skunks had similar detection indices in the park; both were found at approximately one-third of all detection stations (Table 1), particularly at low-elevation areas and within canyons. It is unclear why skunks were not as widespread as raccoons and absent from seemingly high-quality habitat areas such as Royce Canyon. It is unlikely that raccoons are outcompeting skunk in the park; Gehrt (2004) describes differential foraging habits that allow skunks and raccoons to coexist with minimal competition despite the two species being omnivorous and similarly sized. Human activity—in particular deliberate feeding by park visitors (G. Randall, City of Los Angeles, pers. comm.)—may influence the distribution of skunks in Griffith Park, keeping them close to developed areas at the park's border.

A recent study of mammal home range size in San Francisco's Presidio, another urban park, reported a mean home range size of both raccoon and skunk to be 21–25 ha, with a significant amount of overlap between individual home ranges (Boydston 2004). These home range sizes are much smaller than those reported in non-urban studies (e.g., Fritzell 1978, Gehrt 2004), but may be representative of home range sizes of raccoon in Griffith Park, especially given the likelihood of anthropogenic food sources reducing resource competition and need for larger ranges. The data reported by Boydston (2004) suggest that Griffith Park may support dozens of both raccoon and skunk pairs, with numbers likely augmented by animals moving back and forth between the park and the surrounding residential area.

Gray foxes

Gray foxes in Griffith Park appear to be localized, with all detections during this study from the center of the park along the interface between picnic areas and the interior (Old Zoo area). This region of the park, which includes Spring Canyon, supports ample native tree cover and a diversity of habitat types (including oak woodland, sycamore woodland, sumac scrub) as well as permanent water. A study in areas of the Golden Gate National Recreation Area adjacent to cities reported home range sizes of 100.3 ha and 85 ha for female and male gray foxes, respectively (Riley 2006). This suggests that Griffith Park has the potential to support at least as many fox pairs as coyote pairs. However, like bobcats, foxes may be limited by habitat type, human activity, and competition with coyote. Foxes are much less often seen in urban areas than coyotes and, based on track evidence and anecdotal reports from park rangers, appear to be genuinely scarce here.

Opossums

Surprisingly, opossums, frequently observed in urban Los Angeles, had the lowest detection index of any target species in Griffith Park (Table 3). Raccoons have been reported to outcompete opossums (Ladine 1997, Ginger et al. 2003), which could explain the low detection of the species. It is also likely that the opossum has become so urban-adapted in this area that it prefers developed areas to the park due to ease of foraging, as suggested by Boydston (2004) for San Francisco's Presidio. This preference has also been reported for some urban-adapted bird species (Cooper 2002).

Habitat preference

Certain vegetation types, particularly woodland habitats along streams and residential gardens, may be preferred by carnivores to the arid scrub and chaparral of the park; this could explain the higher carnivore diversity found in the low elevation stations. Additionally, proximity to water sources may be especially important for species with small home ranges, especially during periods of seasonal water shortage. This study was conducted at a time of record drought, with only three inches of rainfall between July

2006 and July 2007 (Becerra & Blankstein 2007). Skunks and raccoons were rarely detected at higher elevations; their ranges are relatively small and they may have been limited by access to water sources. Wildlife may have been attracted to food and water sources found in adjacent residential areas and golf courses found on the edges of the park or to the horse troughs and natural springs found at lower elevations.

Low elevation stations may also provide more cover and shade to large mammals than ridges, providing relief from the heat. The increased cover in these areas may be attractive to prey species (e.g., rodents) seeking protection, which in turn would draw predators. Further studies, particularly during the wet season, should be conducted to determine what, if any, seasonal movement shifts are found in the park's wildlife.

Human disturbance

Human disturbance in Griffith Park's interior comes in a variety forms, including hikers, joggers, dog-walkers, and horseback riders, as well as loiterers and transients who set up small encampments in the park's canyons and near parking lots. Numerous studies have documented the impact of human recreation on wildlife (e.g., Whittaker & Knight 1998, Taylor & Knight 2003, George & Crooks 2006). Mammalian carnivores are particularly susceptible to human disturbance because of their low densities and large home ranges, and studies have found that carnivores shift distribution and change behavior in response to human recreation (e.g., White et al. 1999, Ray et al. 2005). A southern California study reported that bobcats and coyotes showed no displacement from equestrian use, but both were affected by hikers with dogs (George & Crooks 2006).

The effect of companion dogs—particularly unleashed dogs—on wildlife is well-documented (reviewed by Lenth et al. 2006). Dogs are reported to disturb wildlife through barking, chasing, scent marking, and disease transmission through defecation. They have also been implicated in disrupting wildlife behavior and habitat use, as well as causing reduced reproductive success for some wildlife (e.g., Yalden & Yalden 1990, Mainini et al. 1993, Miller et al. 2001). While a leash law does exist (L.A.M.C. 53.02), it appears to be rarely obeyed. A casual count by the authors while checking the detection stations in Brush Canyon and Hollywood Ridge on three visits of three hours each totaled 37 dogs off-leash and 18 dogs on-leash.

Brush Canyon, which appeared to be the study area most heavily used by visitors during the study (pers. obs.), exhibited the lowest species diversity, aside from the completely burned Aberdeen sample area. These results are surprising, given that the other oak-sycamore woodland areas of the park (Royce Canyon, Old Zoo) had high carnivore detection rates. Results from our study suggest that current levels of human activity may be limiting the distribution of at least some carnivores within the park. The low carnivore diversity in the Brush Canyon area in particular may reflect an avoidance by large and mid-sized carnivores of an area heavily used by humans. The Skyline trail also has regular hikers and horseback riders, but casual observation during this study indicated that while both areas had comparable equestrian use, Brush Canyon receives many more hikers than Skyline, especially hikers with dogs. This suggests that it may be the presence of hikers accompanied by dogs that is most disruptive to wildlife.

Finally, it should be stressed that this study was conducted only once and over a short period of time. It represents only a snapshot in time within the park, providing baseline information on the presence and distribution of mammalian carnivore species and their habitat needs throughout Griffith Park. Lack of detection by this study does not necessarily mean that other carnivores are not present in the park. Similar studies of wildlife presence and distribution should be conducted several times a year to obtain a more complete understanding of wildlife distribution and account for any possible seasonal movement and dispersal by wildlife. Furthermore, Griffith Park provides a unique opportunity for outdoor recreation within Los Angeles and is thus an invaluable resource for local residents. With this in mind, we recommend that studies on human usage in different areas of the park also be conducted. With a better understanding of the location and distribution of high levels of human recreation, as well as what type of recreation is occurring, we can better study, understand, and mitigate the effects of human activity in the park on resident wildlife.

Acknowledgements

We would like to thank George Grace, Gerry Hans and all of the Griffith Park Master Plan Working Group for proposing, initiating, and funding preliminary wildlife surveys in Griffith Park. The L.A. Department of Recreation and Parks and Department of Water and Power were extremely helpful in coordinating the surveys and granting access to the park. We would like to especially thank Chief Ranger Albert Torres and Rangers Eskander, Joyce, Morales, and Waisgerber. We are also thankful to Gerry and Susan Spehar for, among other things, allowing the use of their van as a field vehicle. Finally, we would like to acknowledge the anonymous reviewers for their insightful reviews and comments on how to improve this manuscript.

Literature Cited

Becerra, H. and A. Blumstein. 2007. Southland at the tinder mercy of a record-breaking dry spell. Los Angeles Times. July 30, p. A1.

Boydston, E.E. 2005. Behavior, ecology, and detection surveys of mammalian carnivores in the Presidio. U.S. Geological Survey, Sacramento, CA. Final Report. 80 pp.

Cooper, D.S. 2002. Geographic associations of breeding bird distribution in an urban open space. Biol. Cons., 104:205–210.

Crooks, K.R. 2002. Relative sensitivities of mammalian carnivores to habitat fragmentation. Conserv. Biol., 16:488–502.

Fleishman, E., D.D. Murphy, and P.F. Brussard. 2000. A new method for selection of umbrella species for conservation planning. Ecol. Appl., 10:569–579.

Fritzell, E.K. 1978. Aspects of raccoon (*Procyon lotor*) social organization. Can. J. Zool., 56:260–271.

Gehrt, S.D. 2004. Ecology and management of striped skunks, raccoons, and coyotes in urban landscapes. Pp. 81–104 *in* People and predators: from conflict to coexistence. (N. Fascione, A. Delach, and M.E. Smith, eds.), Island Press, xvii + 304 pp.

George, S.L. and K.R. Crooks. 2006. Recreation and large mammal activity in an urban nature reserve. Biol. Cons., 133:107–117.

Gese, E.M. 2004. Survey and census techniques for canids. Pp. 273–279 *in* Canids: foxes, wolves, jackals, and dogs. (C. Sillero-Zubiri, M. Hoffman, and D.W. Macdonald, eds.), Information Press, x + 430 pp.

Ginger, S.M., E.C. Hellgren, M.A. Kasparian, L.P. Levesque, D.M. Engle, and D.M. Leslie, Jr. 2003. Niche shift by Virginia opossum following reduction of a putative competitor, the raccoon. J. Mammal., 84:1279–1291.

Harrison, R.L. 2006. A comparison of survey methods for detecting bobcats. Wildl. Soc. Bull., 34: 548–552.

Ladine, T.A. 1997. Activity patterns of co-occurring populations of Virginia opossums (*Didelphis virginiana*) and raccoons (*Procyon lotor*). Mammalia, 61:345–354.

Lenth, B., M. Brennan, and R.L. Knight. 2006. The effects of dogs on wildlife communities. Report to Boulder Country Open Space and Mountain Parks. February, 2006. 29 pp.

Long, R.A., T.M. Donovan, P. Mackay, W.J. Zielinski, and J.S. Buzas. 2007. Comparing scat detection dogs, cameras, and hair snares for surveying carnivores. J. Wildl. Manage., 71:2018–2025.

Manley, P.N., B.V. Horne, J.K. Roth, W.J. Zielinski, M.M. McKenzie, T.J. Weller, F.W. Weckerly, and C. Vojta. 2005. Multiple species inventory and monitoring technical guide, ver. 1.0. United States Department of Agriculture Forest Service, Washington office, 181 pp.

Mainini, B., P. Neuhaus, and P. Ingold. 1993. Behavior of marmots *Marmota marmota* under the influence of different hiking activities. Biol. Cons., 64:161–164.

Meléndrez. 2004. Griffith Park Master Plan. 2nd draft. Available on the World Wide Web (online) http://www.lacity.org/RAP/dos/parks/griffithPK/masterplan2005/masterplan2005.htm. Retrieved Sept. 2007.

Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. da Fonseca, and J. Kent. 2000. Biodiversity hotspots for conservation priorities. Nature, 403:853–858.

Miller, S.G., R.L. Knight, and C.K. Miller. 2001. Wildlife responses to pedestrians and dogs. Wildl. Soc. Bull., 29:124–132.

McDaniel, G.W., K.S. McKelvey, J.R. Squires, and L.F. Ruggiero. 2000. Efficacy of lures and hair snares to detect lynx. Wildl. Soc. Bull., 28:119–123.

Parks, S.A. and A.H. Harcourt. 2002. Reserve size, local human density, and mammalian extinctions in U.S. protected areas. Conserv. Biol., 16:800–808.

Ray, J.C., K.H. Redford, R.S. Steneck, and J. Berger, Eds. 2005. Large carnivores and the conservation of biological diversity. Island Press, xvi + 526 pp.

Schauster, E.R., E.M. Gese, and A.M. Kitchen. 2002. An evaluation of survey methods for monitoring swift fox abundance. Wildl. Soc. Bull., 30:464–477.

Riley, S.P.D. 2006. Spatial ecology of bobcats and gray foxes in urban and rural zones of a national park. J. Wildl. Mangage., 70:1425–1435.

Taylor, A.R. and R.L. Knight. 2003. Wildlife responses to recreation and associated visitor perceptions. Ecol. Appl., 13:951–963.

Tigas, L.A., D.H. Van Vuren, and R.M. Sauvajot. 2002. Behavioral responses of bobcats and coyote to habitat fragmentation and corridors in an urban environment. Biol. Cons., 108:299–306.

United States Census. 2000. Available on the World Wide Web (online) http://www.census.gov/main/www/cen2000.html. Retrieved Sept. 2007.

White, Jr.D., K.C. Kendall, and H.D. Picton. 1999. Potential energetic effects of mountain climbers on foraging grizzly bears. Wildl. Soc. Bull., 27:146–151.

Whittaker, D. and R.L. Knight. 1998. Understanding wildlife responses to humans. Wildl. Soc. Bull., 26: 312–317.

Yalden, P.E. and D. Yalden. 1990. Recreational disturbance of breeding golden plovers *Pluvialis apricarius*. Biol. Cons., 51:243–262.

Accepted for publication 11 December 2007.

Bull. Southern California Acad. Sci.
107(2), 2008, pp. 68–80

A New Early Miocene Species of *Pogonias* (Teleostei: Sciaenidae) Based on Otoliths from California

Gary T. Takeuchi[1] and Richard W. Huddleston[1,2]

[1]*Department of Vertebrate Paleontology, Natural History Museum of Los Angeles County, 900 Exposition Boulevard, Los Angeles, California 90007, gtakeuch@nhm.org*
[2]*Scientific Research Systems, 4432 Earle Avenue, Rosemead, California 91770, rwhuddleston@earthlink.net*

Abstract.—A new species of early Miocene croaker of the genus *Pogonias* (Perciformes: Sciaenidae) from the marine upper Olcese Sand, southeastern San Joaquin Valley, Kern County, California is described based on saccular (=sagittae) otoliths. This is the first fossil record of the genus *Pogonias* from the eastern Pacific Rim. It is hypothesized that this new species of *Pogonias* or its ancestor emigrated from the Gulf Stream of the western Atlantic into the eastern Pacific via the Panama seaway during or prior to the late early Miocene.

Pogonias Lacepède, 1801 in the genus of the family Sciaenidae (croakers or drums), is represented by a single extant species, *P. cromis* Linnaeus, 1766, which is the largest member of the family in the western North Atlantic Ocean (Jones and Wells 1998), with a maximum size of over 117 cm and may weigh as much as 54 kg (Murphy et al. 1998). A long-lived fish, *P. cromis* can reach almost 60 years of age (Jones and Wells 1998). The species occurs along the Atlantic and Gulf of Mexico coasts of America, from Argentina to southern New England (Bigelow and Schroeder 1953), and as far north as the Bay of Fundy (Bleakney 1963). It is common from the Chesapeake Bay south to Florida and most abundant along the Texas coast (Simmons and Breuer 1962). *Pogonias cromis* is a demersal fish of shallow (to 10 m) brackish and marine, subtropical waters, and is usually found over sand and sandy mud substrates in coastal waters. Reported fossil occurrences of *Pogonias* include fish remains from Miocene age deposits of Delaware, Maryland, North Carolina, and Virginia, and Pliocene age deposits of North Carolina.

Paleontological studies of Tertiary teleostean otoliths from California are few and reported detailed descriptions of fossil otolith assemblages are almost nonexistent. This is especially true for the southeastern San Joaquin Basin along the western flank of the Sierra Nevada, California, despite the presence of richly fossiliferous shallow-marine Tertiary sedimentary deposits. These sediments have yielded, in addition to otoliths, abundant marine invertebrates, locally rich concentrations of marine vertebrates, and very rare land mammal remains (Mitchell 1965; Addicott 1970; Savage and Barnes 1972). The late John E. Fitch and field parties in the 1960's and early 1970's intensely bulk sampled matrix from numerous localities for fossil teleostean otoliths from the Barker's Ranch area in the hills to the northeast of Bakersfield, Kern County, California (Huddleston and Takeuchi 2007; Fig. 1). Nearly 1,800 kg of fossiliferous matrix was removed and processed (Clarke and Fitch 1979). This material has produced approximately 21,000 saccular (= sagitta) otoliths, representing at least 67 species belonging in 26 or more families, several thousand teeth of sharks, skates, and rays, *Cetorhinus* sp. (basking shark) gill rakers, and hundreds of squid statoliths. The teleost

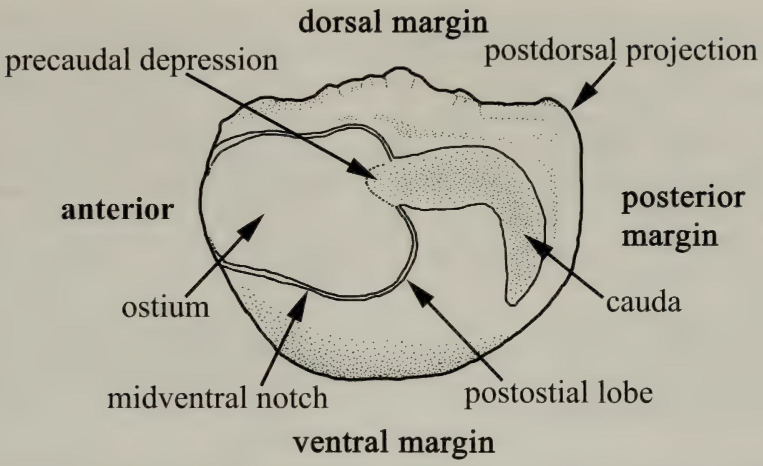


Fig. 1. Diagram of the inner face of a right saccular otolith of *Pogonias* illustrating its various diagnostic features. Modified after Schwarzhans (1993).

assemblage at this site includes pleuronectids and bothids (right- and left-eyed flatfishes), serranids (basses), atherinids (silversides), mugilids (mullets), gobiids (gobies), clupeids (herrings), and other nearshore forms (Clarke and Fitch 1979), but the vast majority of the otoliths are of sciaenids. The Sciaenidae represent approximately 58% of the total number of otoliths (approximately 12,000 of the approximately 21,000 otoliths) and include at least 7 genera.

The Barker's Ranch ichthyofauna lacks a comprehensive faunal study. Some groups, such as the mollusks and other invertebrates, are well documented from the Barker's Ranch area (Addicott 1956, 1965, 1970, 1972; Clarke and Fitch 1979). However, the Barker's Ranch ichthyofauna has been largely untouched except for a few brief reports. Fitch (1969:13, fig. 2d) reported, but did not describe otoliths of the lanternfish *Lampanyctus* in a review of fossil Myctophidae of North America. Clarke and Fitch (1979:492) in a study of fossil teuthoid (cephalopod) statoliths of North America briefly mentioned some of the associated teleost fauna based on otoliths. Olson and Welton (1986:49) listed the selachian taxa and otoliths of unidentified sciaenids and bothids. More recently, the authors have reported a fin spine of the chimaeroid fish *Edaphodon* (Takeuchi and Huddleston 2006) and described the first fossil occurrence of the sciaenid genus *Totoaba* based on saccular otoliths from the Barker's Ranch area (Huddleston and Takeuchi 2007).

We describe here a new late early Miocene species of sciaenid, in the genus *Pogonias* from California based on three saccular otoliths. This is a significant discovery, not only because it is an undescribed form, but also it is the only representative of the genus from the eastern Pacific Rim.

Material and Methods

Otoliths are comprised of three calcium carbonate structures, mainly in the form of aragonite, and organic matter called otoline (Nolf 1985), in the inner ear of teleosts: utricular (lapillus), lagenar (asterisk), and saccular (sagitta). They have been discussed extensively by Nolf (1985) including their anatomy, morphology, variability, ontogenetic changes, and preservation. The saccular otolith is generally the most widely used in comparative morphology because of their large size, degree of interspecific variation, and

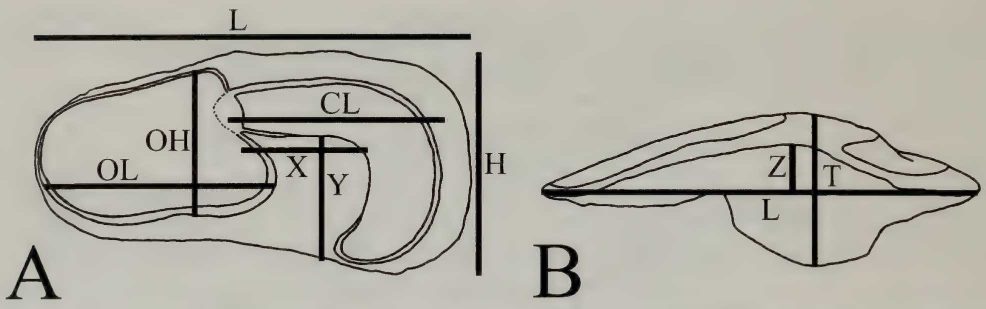


Fig. 2. Generalized sciaenid right saccular otolith illustrating measurements used for proportional ratios. **A.** inner face; **B.** ventral view. **Abbreviations**: **cl**, cauda length; **h**, otolith height; **l**, otolith length; **oh**, ostium height; **ol**, ostium length; **t**, otolith thickness; **l:z**, curvature index of the inner face (cii); **x:y**, caudal curvature index (cci). Modified after Schwarzhans (1993).

ease by which the structures can be accessed (Gaemers 1984; Nolf and Steurbaut 1989; Lombarte et al. 1991). Sciaenid saccular otoliths in particular, are characterized by their large size and diverse morphology (Schwarzhans 1993). The taxonomic identification of fossil otoliths is based on comparative studies with sagittae of the nearest Recent relative (see Nolf 1985; Smale et al. 1995). Fossil otolith assemblages have repeatedly been shown to provide a more detailed and accurate account of Tertiary ichthyofaunas than the exclusive use of isolated skeletal elements or articulated remains (Nolf 1995). Fossil otoliths are found in a wide spectrum of sedimentary environments and are common fossils in many marine sediments, in contrast, the preservation of fish skeletons nearly always represents unusual environmental circumstances (Nolf 1985, 1995). Patterson (1993) in a survey of the fossil record of teleostean fishes showed that among the 244 extant families that do have a fossil record, 58 families (24%) are exclusively recorded from otoliths. In addition, the fossil record for many families is extended considerably geographically and temporally by otoliths (Nolf 1995).

Recent comparative materials used in this study are from the collections of the Department of Ichthyology, Natural History Museum of Los Angeles County, Los Angeles, California (LACM), and include 18 uncatalogued saccular otoliths of *P. cromis*. Additional saccular otoliths of *P. cromis* were provided from the private collection of M. A. Roeder.

The specimens studied are deposited in the collections of the Department of Vertebrate Paleontology, LACM. Undescribed and uncatalogued material from the Barker's Ranch locality is stored in the John E. Fitch Otolith Collection housed in the Department of Ichthyology, LACM. Bulk matrix samples were wet-screened in water to remove the fine fraction and the remaining concentrated matrix was manually sorted under a dissecting microscope to remove identifiable otoliths, teeth, and bones. This method is fully described in Clarke and Fitch (1979:480–481). Specimens were photographed with a Nikon D70 digital camera.

Morphological terms (Fig. 1) used in the general description mainly follow those of Nolf (1985) and Schwarzhans (1993). Linear measurements were made on an EPOI Shopscope optical micrometer. Measurements and proportional ratios of the otolith for the Sciaenidae follow the method proposed by Schwarzhans (1993), and are described below. Otolith measurements are shown on Fig. 2. Measurements used for proportional ratios on the inner face include the following: otolith length (L) is the greatest anterior to posterior length; otolith height (H) is the greatest dorsal to ventral height; ostium length (ol) is taken from the anterior edge of the ostium to the posterior most extension of the ostium, including the postostial lobe, if present; ostium height (oh) is the greatest dorsal to ventral height of the ostium with the otolith in natural position; cauda length (cl) is measured from the dorsal edge of the cauda at the dorsal caudal joint to the posterior most extension of the dorsal caudal margin; length of horizontal portion of the cauda (x) is measured from the caudal joint of the ventral caudal margin to the posterior most extension of the ventral caudal margin; length of down turned portion of cauda (y) is from the highest point of the ventral caudal margin to the ventral most point of the cauda termination. Measurements used for proportional ratios from lateral view: otolith thickness (T), is the greatest inner face to outer face thickness taken in dorsal view; z, is measured from L to the highest point of the ventral margin; curvature index of the inner face (cii), is the ratio of the otolith length (L) to z in dorsal view.

Systematic Paleontology

Class Actinopterygii sensu Nelson, 2006

Division Teleostei sensu Nelson, 2006

Order Perciformes sensu Johnson and Patterson, 1993

Family Sciaenidae Cuvier, 1829

Subfamily Sciaeninae Gill, 1861

Genus *Pogonias* Lacepède, 1801

Type-species.—Pogonias fasciatus Lacepède, 1801

Generic Diagnosis (emended from Schwarzhans 1993).—The saccular otoltih is subovate with a strongly convex inner face and an L:H index of 1.2–1.4. The dorsal margin is semi-flat, except for a strong to moderate mediodorsal dome and low mediodorsal angles. The posterior margin is strongly curved and slightly blunted at its upper edge with a moderate to well developed postdorsal projection. The ventral margin is broadly rounded, as is the anterior margin. The ostium is large and subrectangular, tapering or constricted at the anterior end with an ol:oh index greater than 1.0. The cauda is narrow and steeply curving. The length of the anterior part of the cauda is equal to or less than the length of the posterior part. The outer face is slightly concave, and a tuberculate ornamentation is sometimes present in the area of the postcentral umbo.

Pogonias stringeri, sp. nov.

(Figs. 3–5; Table 1)

Holotype.—LACM 151868, right saccular otolith (Figs. 3, 4A, B).

Paratypes.—LACM 151869, right saccular otolith (Fig. 4C, D); LACM 151870, right saccular otolith (Fig. 4E, F).

Locality and Horizon.—The type locality is in the early Miocene Olcese Sand, part of the Temblor Group, in the southeastern San Joaquin Basin, California, at the "Ledge Site," LACM locality 6602, NW ¼ of Sec. 33, T. 28 S., R. 29 E., (Rio Bravo 7.5′ quadrangle), approximately 13 km northeast of Bakersfield, Kern County, California (Huddleston and Takeuchi 2007; Fig. 1). The specimens studied have been collected from near the top of the upper Olcese Sand (Clarke and Fitch 1979:492; Huddleston and Takeuchi 2007) in a shell bed directly below a calcareously cemented sandstone that is approximately 14 m stratigraphically below a mottled siltstone of the lower Round

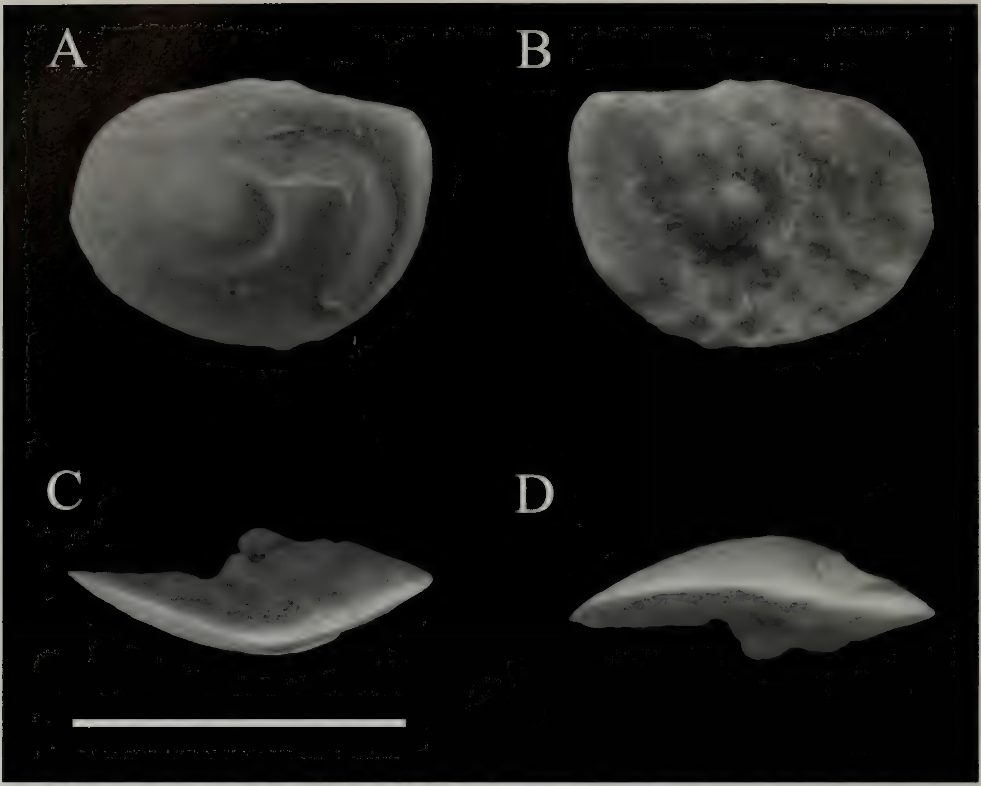


Fig. 3. *Pogonias stringeri* sp. nov. (holotype; LACM 151868), right saccular otolith, late early Miocene, upper Olcese Sand, Kern County, California. **A.** inner face; **B.** outer face; **C.** dorsal view; **D.** ventral view. Scale bar equals 1 cm.

Mountain Silt. The upper Olcese Sand is interpreted to represent shelf deposits that were deposited below normal wave base, signified by the presence of oscillations of storm-induced, wave-formed beds and concentrated shell lags based on abundant mollusks and foraminifera (Addicott 1970; Olson 1990). Recent paleomagnetic studies by Prothero et al. (in press) have correlated the upper member of the Olcese Sand with paleomagnetic Chrons C5Cn2–C5Cn3 (16.1–16.6 Ma), confirming the latest early Miocene age for this unit. The locality is discussed at length in Huddleston and Takeuchi (2007).

Diagnosis.—The saccular otolith of *Pogonias stringeri* is distinguished from the extant *Pogonias cromis* in the following combination of characters: 1) a narrower ostium, constricted anteriorly, with a well developed midventral notch (Fig. 5); 2) a lower rounded mediodorsal angle with a reduced posterior dorsal projection (Fig. 5); and 3) a tubuculate ornamentation in the postcentral umbo area (Fig. 5).

Discussion.—The saccular otolith of *Pogonias stringeri* shows a number of characters diagnostic of Sciaenidae, including: a strongly homosulcoid sulcus, with both the rostrum and antirostrum absent; a broad, flat, shallow ostium with a distinct postostial lobe; and a narrow and horizontal cauda with a curved posterior cauda. The inclusion of the species in the genus *Pogonias* is justified by the presence of the following features: a compressed otolith with deeply rounded ventral rim and shallow dorsal rim; a moderately convex inner face; a strongly enlarged ostium with a ol:oh index larger than 1.0; a short,

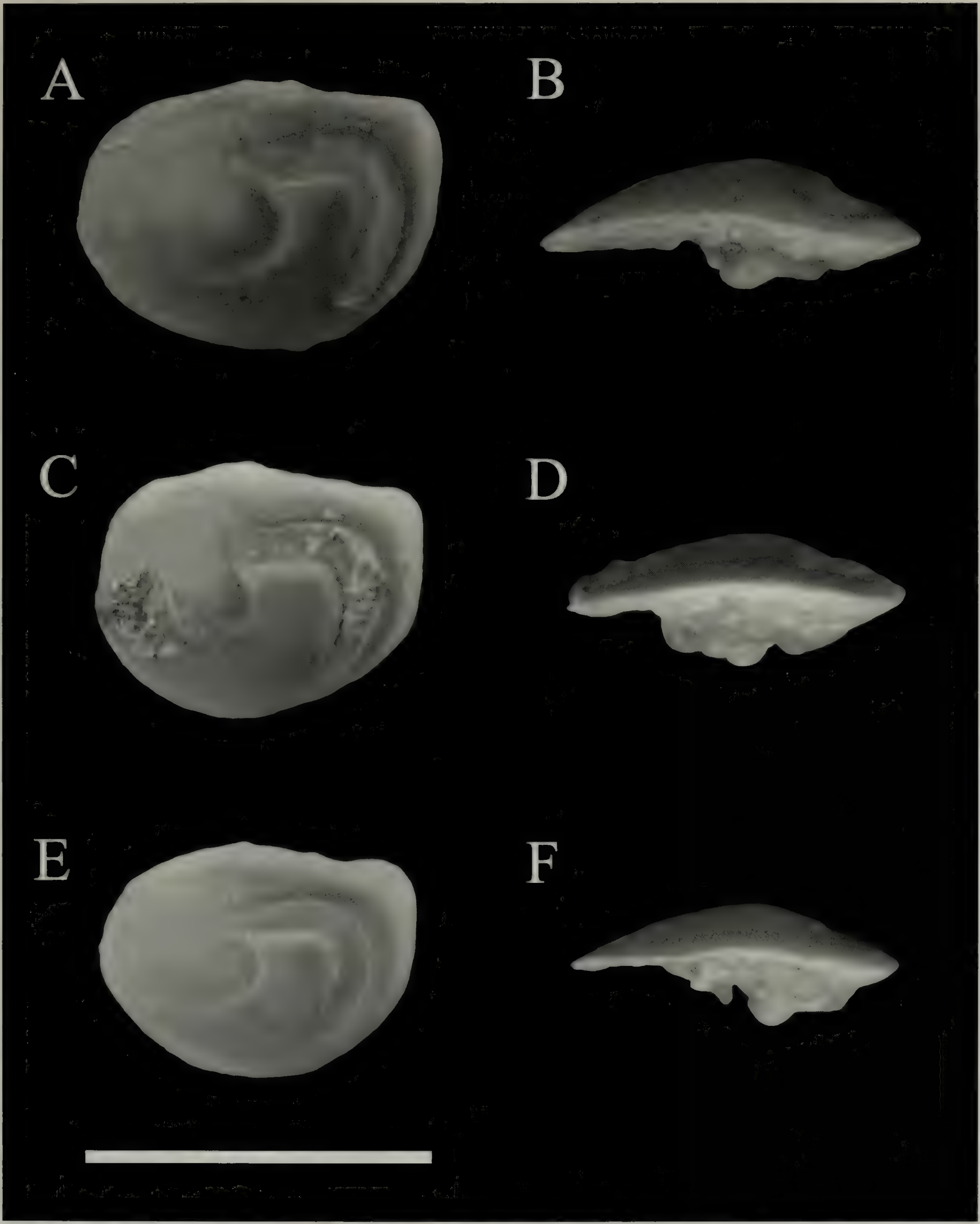


Fig. 4. *Pogonias stringeri* sp. nov. holotype right saccular otolith, LACM 151868, **A.** inner face; **B.** ventral view; paratype right saccular otolith, LACM 151869, **C.** inner face; **D.** ventral view; paratype right saccular otolith, LACM 151870, **E.** inner face; **F.** ventral view. Scale bar equals 1 cm.

narrow, moderately deep and steeply curving cauda; and a sharply pointed, slightly projecting, posterodorsal projection.

Etymology.—The species is named in honor of Dr. Gary L. Stringer, Professor of Geology, University of Louisiana at Monroe, Louisiana in recognition of his contribution to the study of fossil fish otoliths, particularly in the Gulf Coast of North America.

Description.—The holotype of *P. stringeri* (LACM 151868) is a slightly eroded right saccular otolith with a total length of 10.5 mm and a greatest height of 7.9 mm.

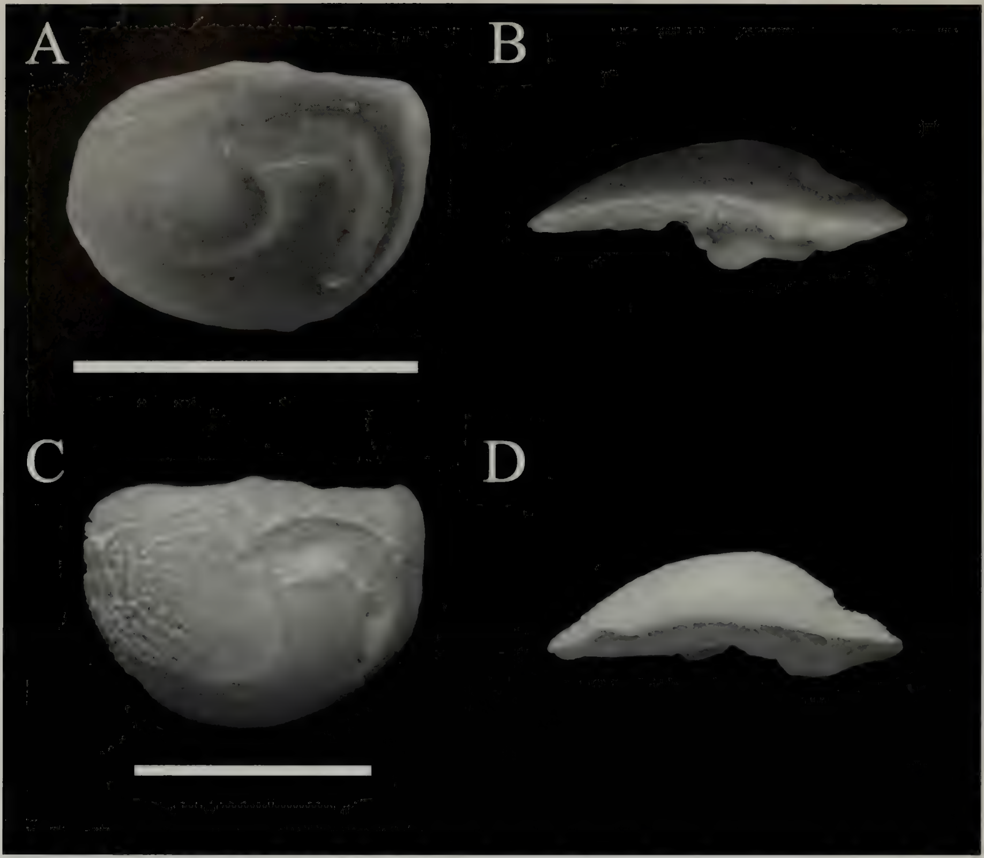


Fig. 5. Saccular otolith of fossil and Recent *Pogonias* species. *Pogonias stringeri* sp. nov. (holotype; LACM 151868), **A.** innerface **B.** ventral view; *Pogonias cromis*, **C.** innerface **D.** ventral view. Scale bars equals 1 cm.

Measurements and proportional ratios for the saccular otolith of *P. stringeri* are summarized in Table 1. The otolith is small, subovate with the inner face strongly convex. The dorsal margin has a low mediodorsal dome and low mediodorsal angles, with a moderate posterodorsal projection. The anterior margin is sharply rounded and posterior margin is strongly curved, with the ventral margin deeply to broadly rounded. The ostium is large, subrectangular, and constricted anteriorly, creating a prominent midventral notch, with a moderate postostial lobe. The precaudal depression is short with a moderately long curved cauda. The anterior cauda is horizontal and shorter than the posterior cauda, which is bent or curved ventrally. The outer face is slightly concave and thick, with a strong tuberculate ornamentation in the postcentral umbo area. The paratypes of *P. stringeri* (LACM 151869 and LACM 151870) vary only slightly from the type in having a slight flattening at the upper edge of the posterior margin (Fig. 4C–F).

Discussion and Conclusions

All prior reported fossil occurrences of *Pogonias* are from the east coast of North America, with a fossil record ranging from Miocene to Pliocene. Purdy (1998:139, plate 2, fig. 24) reported pharyngeal plates and isolated teeth referred to *Pogonias* sp. from the lower shell bed of the Cheswold sands of the early Miocene Calvert Formation, Pollack

Table 1. Comparison of measurements and proportional ratios of the saccular otolith between species of *Pogonias*. **Abbreviations:** **l**, otolith length; **h**, otolith height; **t**, otolith thickness; **ol**, ostium length; **oh**, ostium height; **cl**, caudal length; **x**, horizontal portion of cauda; **y**, down turned portion of cauda; **x:y**, caudal curvature index (cci); **l:z**, curvature index of the inner face (cii). See text and Fig. 3 for definition of abbreviations. Measurements are in mm.

	l	h	t	ol	oh	cl	x	y	z	l:h	h:t	cl:ol	ol:oh	cci	cii
P. stringeri **(adult)**															
LACM 151868 (holotype)	10.5	7.9	3.7	6.0	4.8	4.4	2.8	3.7	2.7	1.33	2.13	0.73	1.25	0.76	3.89
LACM 151869 (paratype)	9.0	6.9	3.6	4.4	3.8	3.8	2.5	3.4	2.0	1.30	1.91	0.86	1.16	0.74	4.50
LACM 151870 (paratype)	8.9	6.7	3.3	4.4	3.4	3.7	2.5	3.0	1.9	1.33	2.03	0.84	1.29	0.83	4.68
Mean	9.46	7.17	3.53	4.93	4.0	3.97	2.60	3.36	2.20	1.32	2.03	0.81	1.23	0.78	4.36
Standard Deviation	0.90	0.64	0.21	0.92	0.72	0.38	0.17	0.35	0.43	0.01	0.11	0.07	0.07	0.05	0.42
Coefficient of Variation	9.46	8.97	5.89	18.72	18.02	9.54	6.66	10.43	19.81	1.07	5.39	8.57	5.63	6.65	9.55
Maximum	10.5	7.9	3.7	6.0	4.8	4.4	2.8	3.7	2.7	1.33	2.13	0.86	1.29	0.83	4.68
Minimum	8.9	6.7	3.3	4.4	3.4	3,7	2.5	3.0	1.9	1.30	1.91	0.73	1.6	0.74	3.89
P. cromis **(adult)**															
Mean	14.15	11.04	3.77	7.47	7.05	5.83	3.95	4.80	3.19	1.28	3.02	0.78	1.07	0.83	4.44
Standard Deviation	2.36	1.65	0.97	1.44	1.54	1.35	0.89	0.95	0.50	0.43	0.44	0.05	0.05	0.10	0.25
Coefficient of Variation	16.70	14.98	25.66	19.23	21.81	23.12	19.73	25.66	15.72	3.39	14.62	6.09	4.87	12.00	5.71
Maximum	18.5	14.2	5.5	9.8	9.4	8.7	5.8	6.5	4.0	1.36	3.63	0.89	1.13	1.00	5.00
Minimum	11.4	9.2	2.7	5.6	5.1	4.2	2.9	3.5	2.6	1.21	2.18	0.72	0.93	0.64	4.14
Number = 15															
P. cromis **(juvenile)**															
Mean	7.3	5.98	1.86	3.62	3.38	2.96	2.14	2.22	1.6	1.22	3.21	0.82	1.07	0.96	4.58
Standard Deviation	0.73	0.58	0.09	0.48	0.35	0.43	0.40	0.34	0.21	0.01	0.25	0.07	0.04	0.08	0.29
Coefficient of Variation	10.07	9.64	4.80	13.30	10.33	14.64	18.87	15.41	13.26	0.79	7.92	8.61	4.15	8.67	6.31
Maximum	7.9	6.4	2.0	4.1	3.7	3.5	2.6	2.5	1.9	1.23	3.56	0.90	1.14	1.04	4.88
Minimum	6.4	5.3	1.8	3.1	3.0	2.5	1.7	1.8	1.4	1.21	2.94	0.71	1.03	0.84	4.11
Number = 5															

Farm Site, Chewold, Delaware. No detailed description of the material was given. Purdy (1998) noted that the fish fauna from the Pollack Farm Site is identical to those of the Calvert and Pungo River formations of Maryland and North Carolina, respectively. Purdy et al. (2001:176, fig. 72 f, g) tentatively assigned upper and lower pharyngeal plates, premaxillae, and isolated pharyngeal teeth to *P. cromis* from the early Miocene Pungo River and the early Pliocene Yorktown formations, Lee Creek Mine, Aurora, North Carolina. Using an upper pharyngeal tooth length/count ratio, they concluded the Lee Creek Mine pharyngeal compared favorably with the extant species. However, they did note some inconsistencies in the shape and articulating surfaces of the fossil specimens. In addition, Fitch and Lavenberg (1983:523) reported a saccular otolith of *Pogonias* cf. *P. cromis*, based on a small (6.1 mm long), badly chipped specimen from the Yorktown Formation. They noted, "the inner face is concave and it has a sharply pointed, slightly projecting posterodorsal corner that is unique to *Pogonias*. In these features and other characters it agrees well with otoliths of *P. cromis*." The specimen was not illustrated. Müller (1999:171, fig. 35/27a–b) in his extensive monograph of the Tertiary bony fish fauna of the U. S. Atlantic Coastal Plain, referred a single incomplete otolith to *Pogonias* sp. from the late Miocene age Little Cove Point Member of the St. Marys Formation, Maryland. He considered the otolith similar to, but distinct from *P. cromis* based on apparent differences of the sulcus, a wider cauda, and a slightly convex outerface. Unfortunately, there was insufficient material to assign this specimen to a species. He also noted that "jaw bones, characteristic pharyngeal teeth and other pharyngeal items of *Pogonias* have also been found in St. Marys Formation (Little Cove Point Member)." Cope (1869) described a nearly complete right upper pharyngeal plate from Nomini Cliffs, Westmoreland County, Virginia, which he named *P. multidentatus*. This pharyngeal plate contains more teeth in the same relative area than the extant species, *P. cromis*. In the area of Nomini Cliffs the Calvert, Choptank, and St. Marys formations are all well exposed at this site and the precise collecting locality is unclear from Cope's (1869) description. Smith (1909) speculated that the type was collected from the late Miocene age St. Marys Formation based on a second specimen referred to *P. multidentatus*.

Fossil material removed from *Pogonias* includes the following: Weinfurter (1952:473–475, pl. 1 fig. 6a–d) described and illustrated a right saccular otolith, "Sciaenidarum" *stryriacus* from the middle Miocene of Austria that he was unable to place taxonomically, and was left in open nomenclature. Schwarzhans (1993:86) tentatively place this species in *Pogonias* based on Weinfurter's (1952) drawings of the otolith and did not review the type or any other material representing the species. However, the type is a strongly eroded non-diagnostic otolith and should be considered as a rejected species (D. Nolf pers. comm., 2006).

Based on the limited fossil record of *Pogonias*, as well as its extant distribution, we suggest the genus or its ancestor evolved entirely in Tropical America during the mid-Tertiary. The family Sciaenidae is a strongly provincialized group of fishes, with nearly all of the 70 extant genera confined to a specific bioprovince (Sasaki 1989). Distribution of extant sciaenids reveals the greatest diversity and highest number of species in two primary regions of the world's oceans, the Indo-West Pacific and Tropical America (on both Pacific and Atlantic sides). Each region may represent a major evolutionary center for sciaenid radiation and dispersal (Chao 1986; Sasaki 1989; Schwarzhans 1993). Sasaki (1989) noted that 14 extant sciaenid genera possess an Amphi-American distribution and the family possibly originated in a restricted area of the New World. The North American otolith-based fossil record of the Sciaenidae strongly supports the hypothesis that Tropical America was the major evolutionary center for this family. The earliest geologic occurrence of the family is from middle to late Eocene deposits of the Gulf Coast region of North America (Koken 1888; Frizzell and Dante 1965; Breard and Stringer 1999; Nolf 2003; Nolf and Stringer 2003) and the family does not appear in the European fossil record until the Relian (lower Oligocene). Remarkably, sciaenids are totally absent from otolith-rich Eocene deposits in California. They first appear in the early Miocene (ca 23 Ma) Jewett Sand Formation in central California and consist of a small poorly preserved fauna including several undescribed taxa. By the late early Miocene the family is well established in the eastern Pacific and is reflected in the occurrence of at least 7 genera from the Barker's Ranch locality (LACM locality 6602). This has led us to hypothesize that the family initially invaded the eastern Pacific from the Gulf Coast region through the Panamanian Seaway sometime after the Eocene (Huddleston and Takeuchi 2006) and *Pogonias* or its ancestor evolved in the Gulf Coast/Western Atlantic coastal region prior to its dispersal into the Eastern Pacific.

The presence of *Pogonias* in the eastern north Pacific realm during the late early Miocene is particularly significant from a biogeographic point of view. Its presence in the eastern north Pacific could be explained by an expanded area of distribution of this genus today restricted to the Atlantic shores of America. A wider distribution of these fishes was probably related to the Panama seaway, which formed a corridor linking the modern eastern Pacific and Atlantic during much of the Tertiary. Assuming fossil sciaenids had similar ecological preferences to Recent sciaenids, this seaway made it possible for nearshore fishes, such as *Pogonias*, to move along subtropic shorelines, which are now disrupted. The vicariant closure of the seaway with the uplift of the Isthmus of Panama occurred between 3.7 and 3.0 Ma (Duque-Caro 1990; Coates et al. 1992; Coates and Obando 1996; Ibaraki 1997), dividing a former single bioprovince in two; separating the Pacific faunas and the Atlantic faunas. In addition to ecological and evolutionary effects, the emergence of the isthmus caused substantial variations in regional surface water temperature, changes in oceanic circulation (Keigwin 1978, 1982), modifications of sedimentation rates, variations of climatic marine conditions in both the Atlantic and Pacific oceans, and an increase of salinity in the Caribbean Sea and western Atlantic (Coates and Obando 1996; Ibaraki 1997). This was not a single event and had major biological effects on marine organisms that are likely to have spread since the late Miocene (Coates and Obando 1996; Collins 1996).

Acknowledgments

We are especially indebted to the late J. E. Fitch and field parties who first found the locality, initiated excavations there, and collected the otoliths used in this study. R. F. Feeney, J. A. Seigel, and C. E. Thacker (Department of Ichthyology, LACM) provided access to otoliths of extant and fossils sciaenids from the John E. Fitch Otolith Collection. M. A. Roeder graciously provided additional otoliths of *P. cromis* from his personal collection for this study. We especially thank D. Nolf (Royal Belgium Institute of Natural Sciences, Brussels) for providing us with important references and invaluable discussions on sciaenid otoliths and D. Prothero (Occidental College) for information and discussions on the upper Olcese Sand. Many helpful comments on a draft of the manuscript were given by J. M. Harris and D. Nolf, and a review by H. Fierstine. Preliminary results of this project were presented at the 60th Annual Meeting of the Society of Vertebrate Paleontology.

Literature Cited

Addicott, W.O. 1956. Miocene stratigraphy northeast of Bakersfield, California. Ph.D. dissertation. Paleontology, University of California, Berkeley, California. 207 pp.

———. 1965. Miocene macrofossils of the southeastern San Joaquin Valley, California. U. S. Geol. Surv. Prof. Pap., 525C:101C–109C.

———. 1970. Miocene gastropods and biostratigraphy of the Kern River area, California. U. S. Geol. Surv. Prof. Pap., 642:1–174.

———. 1972. Provincial middle and late Tertiary molluscan stages, Temblor Range, California. Pp. 1–26 *in* Proceedings of the Pacific Coast Miocene Biostratigraphic Symposium. (E.H. Stinemeyer, ed.), SEPM, 364 pp.

Bigelow, H.B. and W.C. Schroeder. 1953. Fishes of the Gulf of Maine. U. S. Fish Wildl. Serv. Fish. Bull., 53:1–577.

Bleakney, J.S. 1963. First record of the fish *Pogonias cromis* from Canadian waters. Copeia, 1963(1):173.

Breard, S.Q. and G.L. Stringer. 1999. Integrated paleoecology and marine vertebrate fauna of the Stone City Formation (middle Eocene), Brazos River section, Texas. Trans. Gulf Coast Assoc. Geol. Soc., 49:132–142.

Chao, L.N. 1986. A synopsis on zoogeography of the Sciaenidae. Pp. 570–589 *in* Indo-Pacific fish biology: Proceedings of the Second International Conference of Indo-Pacific Fishes. (T. Uyeno, R. Arai, T. Taniuchi, and K. Matsuura, eds.), Ichthyological Society of Japan, Tokyo. 985 pp.

Clarke, M.E. and J.E. Fitch. 1979. Statoliths of Cenozoic teuthoid cephalopods from North America. Palaeontology, 22:479–511.

Coates, A.G. and F.A. Obando. 1996. The geologic evolution of the Central American Isthmus. Pp. 21–56 *in* Evolution and environment in tropical America. (J.B.C. Jackson, A.F. Budd, and A.G. Coates, eds.), Univ. Chicago Press, Chicago, Ill., 425 pp.

———, J.B.C. Jackson, L.S. Collins, T.M. Cronin, H.J. Dowsett, L.M. Bybell, P. Jung, and J.A. Obando. 1992. Closure of the Isthmus of Panama: the near-shore marine record of Costa Rica and western Panama. Geol. Soc. of Amer. Bull., 104:814–828.

Collins, L.S. 1996. Environmental changes in Caribbean shallow waters relative to the closing tropical American seaway. Pp. 130–167 *in* Evolution and environment in tropical America. (J.B.C. Jackson, A.F. Budd, and A.G. Coates, eds.), Univ. Chicago Press, Chicago, Ill., 425 pp.

Cope, E.D. 1869. Description of some extinct fishes previously unknown. Proc. Boston Soc. Nat. Hist., 12: 310–317.

Cuvier, G. 1829. Le Règne Animal, distribué d'après son organisation, pour servir de base à l'histoire naturelle des animaux et d'introduction à l'anatomie comparée, Nouvelle édition. Paris, 2:122–406.

Duque-Caro, H. 1990. Neogene stratigraphy, paleoceanography and paleobiogeography in northwest South America and the evolution of the Panamanian seaway. Palaeogeogr. Palaeoclimatol. Palaeoecol., 77:203–234.

Fitch, J.E. 1969. Fossil lanternfish otoliths of California, with notes on fossil Myctophidae of North America. Los Angeles County Mus. Contrib. Sci., 173:1–20.

——— and R.J. Lavenberg. 1983. Fish Otoliths from Lee Creek Mine, Aurora, North Carolina (Yorktown Formation: Pliocene). Pp. 509–529 *in* Geology and Paleontology of the Lee Creek Mine, North Carolina, I. (C.E. Ray, ed.), Smithson. Contrib. Paleobiol., 53, vi + 529 pp.

Frizzell, D. and J. Dante. 1965. Otoliths of some early Cenozoic fishes of the Gulf Coast. J. Paleontol., 39: 687–718.

Gaemers, P.M. 1984. Taxonomic position of the Cichlidae (Pisces, Perciformes) as demonstrated by the morphology of their otoliths. Neth. J. Zool., 34:566–595.

Gill, T.N. 1861. Revision of the genera of North American Sciaeninae. Proc. Acad. Nat. Sci. Phila., 13: 79–89.

Huddleston, R.W. and G.T. Takeuchi. 2006. A new late Miocene species of sciaenid fish, based primarily on an *in situ* otolith from California. Bull. Southern California Acad. Sci., 105(1):30–42.

——— and ———. 2007. First fossil record of *Totoaba* Villamar 1980 (Teleostei: Sciaenidae) based on early Miocene otoliths from California with comments on the ontogeny of the saccular otolith. Bull. Southern California Acad. Sci., 106(1):1–15.

Ibaraki, H. 1997. Closing of the Central American Seaway and Neogene coastal upwelling along the Pacific coast of South America. Tectonophysics, 281(1–2):99–104.

Johnson, G.D. and C. Patterson. 1993. Percomorph phylogeny: a survey of the acanthomorphs and a new proposal. Pp. 554–626 *in* Proceedings of the symposium on phylogeny of Percomorpha, June 15–17, held in Charleston, South Carolina at the 70th annual meeting of the American Society of Ichthyologists and Herpetologists. (G.D. Johnson and W.D. Anderson, Jr., eds.), Bull. Marine Sci., 52:1–629.

Jones, C.J. and B.K. Wells. 1998. Age, growth, and mortality of black drum, *Pogonias cromis*, in the Chesapeake Bay region. Fish. Bull., 96:451–461.

Keigwin, L.D. Jr. 1978. Pliocene closing of the Isthmus of Panama, based on biostratigraphic evidence from nearby Pacific ocean and Caribbean sea cores. Geology, 6:630–634.

———. 1982. Isotopic paleoceanography of the Caribbean and East Pacific: role of Panama uplift in Late Neogene time. Science, 217:350–353.

Koken, E. 1888. Neue untersuchungen an Tertiären fischotolithen. Z. deut. Geol. Ges., 40:274–305.

Lacepède, B.G.E. 1801. Histoire naturelle des poissons. Hist. Nat. Poiss, 3:1–558.

Linnaeus, C. 1766. Systema naturae sive regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Laurentii Salvii, Holmiae, 12th ed. Systema Nat. ed. 12:1–532.

Lombarte, A., J. Rucabado, J. Matallana, and D. Lloris. 1991. Taxonomica numerica de Nototheniidae en base a la forma de los otolitos. Sci. Mar., 55(2):413–418.

Mitchell, E.D. 1965. History of research at sharktooth Hill, Kern County, California. Kern Co. Hist. Soc., 1–45.

Müller, A. 1999. Ichthyofaunen aus dem atlantischen Tertiär der USA. Leipz. Geowiss., 9/10:1360.

Murphy, M.D., D.H. Adams, D.M. Tremain, and B.L. Winner. 1998. Direct validation of ages determined for adult black drum, *Pogonias cromis*, in east-central Florida with notes on black drum migration. Fish. Bull., 96(2):382–387.

Nelson, J.S. 2006. Fishes of the world, 4th ed. John Wiley and Sons, Inc., Hoboken, New Jersey. xix + 601 pp.

Nolf, D. 1985. Otolithi piscium. Pp. 1–145 *in* Handbook of Paleoichthyology Vol. 10. (H.-P. Schultze, ed.), Gustav Fischer Verlag, Stuttgart and New York.

———. 1995. Studies on fossil otoliths - the state of the art. Pp. 513–544 *in* Recent developments in fish otolith research. (D.H. Secor, J.M. Dean, and S.E. Campana, eds.), Univ. South Carolina Press, 735 pp.

———. 2003. Revision of the American otolith-based fish species described by Koken in 1888. Lou. Geol. Surv., 12:1–19.

——— and E. Steurbaut. 1989. Evidence from otoliths for establishing relationships within gadiforms. Pp. 89–111 *in* Papers on the systematics of gadiform fishes. (D.M. Cohen, ed.), Nat. Hist. Mus. Los Angeles Co. Sci. Ser., 32, ix + 262 pp.

——— and G.L. Stringer. 2003. Late Eocene (Priabonian) fish otoliths from the Yazoo Clay at Copenhagen, Louisiana. Lou. Geol. Surv., 13:1–23.

Olson, H.C. 1990. Early and middle Miocene foraminiferal paleoenvironments, southeastern San Joaquin basin, California. J. Foramin. Res., 20(4):289–311.

——— and B.J. Welton. 1986. Foraminifera and fishes of Tertiary units in the Bakersfield, California area. 1986 Guidebook Pacific Section AAPG meeting, Bakersfield, California,, Pp. 47–49.

Patterson, C. 1993. Osteichthyes: Teleostei. Pp. 621–656 *in* The Fossil Record 2. (J.M. Benton, ed.), Chapman and Hall, London. xvii + 845 pp.

Prothero, D.L., F. Sanchez, and L.L. Denke. In Press. Magnectic stratigraphy of the early to middle Miocene Olcese Sand and Round Mountain Silt, Kern County, California. Bull. New Mexico Mus. Nat. Hist. Sci.

Purdy, R.W. 1998. The early Miocene fish fauna from the Pollack Farm Site, Delaware. Pp. 133–139 *in* Geology and Paleontology of the lower Miocene Pollack Farm Fossil Site, Delaware. (R.N. Benson, ed.), Delaware Geol. Surv. Special Publication 21, 185 pp.

———, V.P. Schneider, S.P. Applegate, J.H. McLellan, R.L. Meyer, and B.H. Slaughter. 2001. The Neogene sharks, rays, and bony fishes from Lee Creek Mine, Aurora, North Carolina. Pp. 71–202 *in* Geology and Paleontology of the Lee Creek Mine, North Carolina, III. (C.E. Ray and D.J. Bohaska, eds.), Smithson. Contrib. Paleobiol., 90, iv + 365 pp.

Sasaki, K. 1989. Phylogeny of the family Sciaenidae, with notes on its zoogeography (Teleostei, Perciformes). Mem. Fac. Fish. Hokkaido Univ., 36(1/2):1–137.

Savage, D.E. and L.G. Barnes. 1972. Miocene vertebrate geochronology of the west coast of North America. Pp. 124–145 *in* Proceedings of the Pacific Coast Miocene Biostratigraphic Symposium. (E.H. Stinemeyer, ed.), SEPM, 364 pp.

Schwarzhans, W. 1993. A comparative morphological treatise of recent and fossil otoliths of the family Sciaenidae (Perciformes), 1. *In* Piscium Catalogus, Otolithi Piscium. (F. Pfeil, ed.), Verlag Dr. Friedrich Pfeil, Munchen, 245 pp.

Simmons, E.G. and J.P. Breuer. 1962. A study of redfish, *Sciaenops ocellata* Linnaeus, and black drum, *Pogonias cromis* Linnaeus. Publ. Inst. Mar. Sci. Univ. Tex., 8:184–211.

Smale, M.J., G. Watson, and T. Hecht. 1995. Otolith atlas of Southern African marine fishes. Ichthyol. Monogr., J. L. B. Smith Inst. Ichthyol., 1:1–253.

Smith, B. 1909. Note on the Miocene drum fish – *Pogonias multidentatus* Cope. Amer. J. Sci., 28:275–282.

Takeuchi, G.T. and R.W. Huddleston. 2006. A Miocene chimaeroid fin spine from Kern County, California. Bull. Southern California Acad. Sci., 105(2):85–90.

Weinfurter, E. 1952. Die otolithen der Wetzelsdorfer Schichten und des Florianer Tegels (Miozän, Steiermark). Sitz.-Ber. Osterr. Akad. Wiss. Math.-natur. Kl., Abt. 1, 161:455–498.

Accepted for publication 12 October 2007.

ANNUAL MEETING

SOUTHERN CALIFORNIA ACADEMY OF SCIENCES

May 2-3, 2008

FOUNDED 1891
INCORPORATED 1907
LOS ANGELES

California State University

Dominguez Hills

Bull. Southern California Acad. Sci.
107(2), 2008, pp. 82–83

Future SCAS Meetings

2009 – Loyola Marymount U., Palos Verdes

Acknowlegements

The Southern California Academy of Sciences wishes to acknowledge the following organizations and people for their support of the 2004 Annual Meeting.

The Port of Los Angeles

PSOMAS

MBC Applied Environmental Sciences

Dean's Office, College of Natural and Behavioral Sciences, CSUDH

Center for Urban Environmental Research (CUER), CSUDH

Jaime Leal, Loker University Student Union

Special thanks to the SCAS 2008 Annual Meeting Local Committee at SCUDH

Dr. Katherine Bates
Dr. Rod HayDr.
Dr. Terry McGlynnDr.
Dr. John Thomlinson
Dr. Janine Gasco
Gus McCarthy
John Roberts, Chair
Dr. Connie Vadheim

Research Training Program; Committee Members and Judges

Tetsuo Otsuki
Richard Schwartz
Phillippa Drennan
Kathy Phalen
Harry Takahashi
Robert F.Phalen
Gloria Takahashi
Jon Baskin
Katherine Bates
Andrea Murray
John Roberts
Dan Guthrie
Robert N. Phalen
John Carvalho
Martha Schwartz
John Dorsey
Bob Grove
Helen Chun

SOUTHERN CALIFORNIA ACADEMY OF SCIENCES ANNUAL MEETING STUDENT PRESENTATION AWARDS

Over 40 students entered this ear's competition for SCAS student-presentation awards. Awards were given in the categories of Biological and Physical Sciences for both posters and talks. Owing to the large number of student presentations in both categories of the Biological Sciences, two Honorable Mention awards were given. First-place award winners received $200 and a one-year membership to the Academy. Honorable mention winners received $100 and a one-year membership to the Academy.

Membership

The academy is always seeking new members and members who would like to become more involved in our activities by serving on our Board of Directors. The board meets once a month to plan and direct the society's activities, which include the annual meeting, publication of the bulletin, offering financial support to graduate students, and operating a Research Training Program for high school students.

Physical Sciences – 1st Place Talk

Rachel Andrus. California State University, Los Angeles. *MOBILITY OF SELENIUM AND NITRATE ALONG A SHALLOW GROUNDWATER FLOWPATH, ORANGE COUNTY, CALIFORNIA*

Physical Sciences – Honorable Mention Talk

Shelby Harrell. California State University, San Bernardino. *A STUDY OF GEOTHERMAL SPRINGS IN NORTHERN DOMINICA*

Biological Sciences – 1st Place Talk

Jeanette Hendricks. California State University, Fullerton. *FORAGING ECOLOGY OF THE ELEGANT TERN IN RESPONSE TO NEW MARINE HABITAT AT THE RESTORED BOLSA CHICA ECOLOGICAL RESERVE*

Biological Sciences – Honorable Mention Talk

Aaron Ramirez. California State University, Bakersfield. *DEER BROWSE AFFECTS ON POST-FIRE COASTAL SAGE REGENERATION ON SANTA CATALINA ISLAND*

Bethany Williams. California State University, Fullerton. *SONG PLAYBACK EXPERIMENTS IN ANNA'S AND COSTA'S HUMMINGBIRDS*

Biological Sciences – 1st Place Poster

Rebecca Hernandez. California State University, Fullerton. *THE EFFECTS OF DISTURBANCE OF BIOLOGICAL SOIL CRUSTS ON THE GERMINATION OF EXOTIC PLANTS IN COASTAL SAGE SCRUB*

Biological Sciences – Honorable Mention Poster

Francisca Herrera. California State Polytechnic University, Pomona. *EFFECTS OF SMALL-SCALE DISTURBANCE ON SEED BANK SPECIES IN A COASTAL SAGE SCRUB COMMUNITY*

Kimberly Nelson. California State University, Fullerton. *EFFECTS OF ANTHROPOGENIC WATER INPUTS ON ARGENTINE ANT INVASION IN RIPARIAN AREAS OF SOUTHERN ORANGE COUNTY*

Student Grants

The Southern California Academy of Sciences supports a program of Grants to graduate students. One stipulation for the winners is that they present their research at the following year's Annual Meeting. This years award winners were

Lisa Komoroske, San Diego State University

Contaminant levels in the East Pacific green turtle *(Chelonia mydas)* and its ecosystem in the San Diego Bay, CA

Stephen M. Trbovich, California State University, Long Beach

Genetic Population Differences of Kelp Bass (*Paralabrax clathratus*) in the Southern California Channel Islands: Effects of Complex Current Systems on Gene Flow

Bull. Southern California Acad. Sci.
107(2), 2008, p. 84

ALPHABETICAL LIST OF PRESENTERS

Name	Abstract
Edith B. Allen	10
Joyce Amaro	22
Rachel Andrus	102
Carl Bell	6
Michael Bell	44
Wendy Billock	99
Geoff Brosseau	21
Brandon Browne	58
Tishy-Linda M. Bunk	63
Donald G. Buth	64
John Campo	65
Pat M. Carter	47
Joyce Chai	112
Debra Chang	116
Chris Crompton	120
Makena Crowe	109
Christina D'Anna	94
Ann Dalkey	66,115
George Daly	60
Sandra DeSimone	19
Sara Jo Dickens	67
Brian Diep	111
K. Dreher	24
Philippa M Drennan	96
Sabrina Drill	7
Sarah English	97
Todd C. Esque	4
Stacie M. Fejtek	32
Robert Fisher	1
Suzanne Fitz-Gonzalez	46
Brad Fowler	27
Janine Gasco	90
Leah Goldstein	14
Mary Greas	68
Julie Guerin	69
Richard Halsey	8
Shelby Harrell	61
James Harwood	54
Mark Helvey	38
Jeanette Hendricks	48
Rebecca R. Hernandez	70
Francisca Herrera	72
James Holmquist	49
David A. Holway	18
Anna Jacobsen	11
Kurt Karageorge	30
T. Kasper	91
Jon E. Keeley	9,15
Serra Lynn Kelley	73
Miyako Kodama	101
Niree Kodaverdian	74
J. Krug	100
Tihomas Kwong	114
Vicky H. Lee	98
Bonnie Lei	108
Brain Li	119

Name	Abstract
Christi Linardich	75
Vanessa Lopez	76
Angela Louie	42
Kimberly Y. Lyman	20
Melissa C. Mandrup	29
Christopher Martin	36
Anthony E. Metcalf	2
Brian Meux	33
Eric Miller	31
Victoria Minnich	77
Stephanie Montgomery	78
Christopher Moore	5
Jerry Moore	93,95
Kimberly Nelson	79
Becky Niemiec	117
Alice Okumura	80
M. Osmund	39
Kevin Pan	113
Ed Parnell	35
Eric Peralta	50
Ana Pitchon	45
Daniel Pondella	37
Kristine Preston	17
Joy Rae Radecki	82
Meredith Raith	51
Aaron Ramirez	13
Edith Read	25
D. Reed	34
Rick Redak	3
Erin Riordan	16
Lily Sam	52
Yareli Sanchez	83
Johannes H. Schellekens	59
Morad Sedrak	26
Neal Shapiro	23,28
Rasoul Sharifi	12
Sarine Shahmirian	107
Shelley Shaul	84
Alan L. Smith	62
Stephen M. Stohs	43
Jane Suh	85
Yonat Swimmer	41
Stephen M. Trbovich	103
Kent Trego	55,56,57
Khristine Tulio	71
Sonja Ulrich	92
Lauren Velasco	86
Anirudh Venkatesh	106
Kimberly Walker	87
Jingyi Jenny Wang	105
Stephen Wertz	40
Bethany Williams	53
Helena (Hao) Wu	89,110
Timothy Wu	88,104
Emily Yang	118

Southern California Academy of Sciences 2008 Session Schedule

Friday, May 2, 2008
Location: LU Student Union 324

Session: Wildland Fire and Wildlife Habitat

Chair: Sabrina Drill, UC Cooperative Extension

1 8:00 IMPACTS OF POST-FIRE GEOLOGICAL PROCESSES ON AMPHIBIAN AND FISH HABITAT IN SOUTHERN CALIFORNIA.
R.N. Fisher, A.R. Backlin, C.J. Rochester, and S.H. Cannon. USGS Western Ecological Research Center, San Diego, CA, rfisher@usgs.gov, abacklin@usgs.gov, crochester@usgs.gov; USGS Central Region Geologic Hazards Team, Denver, CO, cannon@usgs.gov

2 8:20 IMPACTS OF FIRE ON SANTA ANA SPECKLED DACE: A REDUCTION OF POPULATION AND GENETIC BIODIVERSITY IN SOUTHERN CALIFORNIA
A.E. Metcalf, P. VanMeter and J. VanMeter. Dept. of Biology, California State University, San Bernardino, 5500 University Pkwy, San Bernardino, CA 92407

3 8:40 ARTHROPOD RECOLONIZATION AFTER DISTURBANCE BY FIRE: THE IMPORTANCE OF LOCAL VS. LANDSCAPE PROCESSES.
R. A. Redak and J. C. Burger, Department of Entomology, John T. Rotenberry, Department of Biology, University of California, Riverside, 92521 and M. A. Patten, Oklahoma Biological Survey, Norman Oklahoma 73019

4 9:00 A SHORT-TERM EVALUATION OF A LONG-TERM RESEARCH PROBLEM: DESERT TORTOISES, THEIR HABITATS AND FIRE.
T.C. Esque, K. Drake, L.A. DeFalco, K.E. Nussear, S. Scoles-Sciulla, and P.A. Medica, US Geological Survey, Western Ecological Research Center, 160 N. Stephanie St., Henderson, Nevada 89074.

5 E 9:20 EFFECTS OF FIRE ON RODENTS IN SAGEBRUSH-JUNIPER HABITATS OF THE MOJAVE DESERT.
C.M. Moore and P. Stapp, California State University, Fullerton, Department of Biological Science, Fullerton, CA, 92831.

6 9:40 ACTIVE MANAGEMENT AIDS RECOVERY OF BURNT NATURAL LANDSCAPES
Carl E. Bell, Regional Advisor – Invasive Plants, University of California Cooperative Extension, San Diego, CA 92123

10:00–10:20 BREAK

10:20 NEW RESEARCH PRIORITIES, QUESTION AND ANSWER SESSION
Tom Scott, UC Riverside, University of California Cooperative Ext.

7 10:40 SUSTAINABLE AND FIRE-SAFE LANDSCAPES
Sabrina Drill, UC Cooperative Extension - Los Angeles County, 4800 E. Cesar E. Chavez Ave., Los Angeles, CA 90022

8 11:00 CHAPARRAL DOES NOT "NEED" TO BURN: CORRECTING FIRE ECOLOGY MYTHS ABOUT MEDITERRANEAN SHRUBLANDS.
Richard W. Halsey, Director, California Chaparral Institute, PO Box 545, Escondido, CA 92033

11:30–12:30 **Plenary Lecture: LaCorte Hall A-103**

Jon E. Keeley, USGS, Western Ecological Research Center, Sequoia-Kings Canyon Field Station, Three Rivers, CA 93271, USA, and Department of Ecology and Evolutionary Biology, University of California, Los Angeles, CA 90095, USA

9 "FIRE AS AN ECOSYSTEM PROCESS: PAST, PRESENT AND FUTURE"

12:30–1:20 LUNCH BREAK

Friday, May 2, 2008
Location: LU Student Union 324

Session: Ecology and Conservation of California Sage Scrub

Chair: Daren Sandquist, CSU Fullerton

10 1:20 **EFFECTS OF N DEPOSITION ON RIVERSIDEAN SAGE SCRUB**
Edith B. Allen, Department of Botany and Plant Sciences, University of California, Riverside, 92521

11 1:40 **COASTAL SAGE WATER RELATIONS AND POTENTIAL INVASIBILITY**
A.L. Jacobsen and R.B. Pratt. California State University, Bakersfield, Department of Biology, Bakersfield, CA, 93311.

12 2:00 **ECOPHYSIOLOGY OF COASTAL SAGE SCRUB OF SOUTHERN CALIFORNIA**
R. Sharifi and P.W.Rundel. Department of Ecology and Evolutionary Biology, Los Angeles, CA 90095.

13 E 2:20 **DEER BROWSE AFFECTS ON POST-FIRE COASTAL SAGE REGENERATION ON SANTA CATALINA ISLAND.**
A.R. Ramirez[1], R.B. Pratt[1], A.L. Jacobsen[1], S.D. Davis[2]: [1]California State University, Bakersfield, Department of Biology, Bakersfield, CA 93311, [2] Pepperdine University, Natural Science Division, Malibu, CA 90263.

14 E 2:40 **THE ROLE OF RAINFALL PULSES, RESOURCE AVAILABILITY, AND FIRE IN THE CONVERSION OF COASTAL SAGE SCRUB TO ANNUAL GRASSLAND COMMUNITIES**
Leah Goldstein, Matt Talluto, Eva Hernandez, and Katharine Suding. Department of Ecology and Evolutionary Biology, University of California, Irvine, CA 92697

3:00–3:20 **BREAK**

15 3:20 **DIVERSITY PATTERNS IN CALIFORNIA SAGE SCRUB**
Jon E. Keeley[1,2], C.J. Fotheringham[2], Melanie Baer-Keeley[3], and James B. Grace[4], [1]USGS, Western Ecological Research Center, Sequoia-Kings Canyon Field Station, Three Rivers, CA 93271, [2]Department of Ecology & Evolutionary Biology, University of California, Los Angeles, CA 90095, [3]Resources Division, Sequoia National Park, Three Rivers, CA 93271, [4]USGS, National Wetlands Research Center, Lafayette, LA, 70506.

16 E 3:40 **CLIMATE ENVELOPE MODELING IN CALIFORNIA SAGE SCRUB: DEFINING THE BIOCLIMATIC NICHE**
E. C. Riordan and P.W. Rundel. University of California, Los Angeles, Department of Ecology and Evolutionary Biology, Los Angeles, CA, 90095.

17 4:00 **ENVIRONMENTAL DRIVERS OF LANDSCAPE-SCALE COASTAL SAGE SCRUB CONVERSION TO EXOTIC GRASSLAND**
K.L. Preston[1], P. Sadler[2], R. Johnson[1], G. Miller[2] and E. Allen[3] [1]Center for Conservation Biology, University of California Riverside, 1303 Webber Hall, Riverside, CA 92521; [2]Department of Earth Sciences, UC Riverside, Riverside, CA 92521; [3]Department of Botany and Plant Sciences, UC Riverside, 2129 Bachelor Hall, Riverside, CA 92521

18 4:20 **IMPACTS OF ARGENTINE ANTS ON COMMUNITY PROCESSES IN CALIFORNIA SAGE SCRUB.**
D.A. Holway. Section of Ecology, Behavior & Evolution, Division of Biological Sciences, University of California at San Diego, MC 0116, 9500 Gilman Drive, La Jolla, CA 92093-0116.

19 4:40 **COASTAL SAGE SCRUB RESTORATION AT AN AUDUBON CALIFORNIA SANCTUARY: A RESEARCH-BASED, NON-CHEMICAL APPROACH**
S. A. DeSimone. Audubon California's Starr Ranch Sanctuary, 100 Bell Canyon Rd., Trabuco Canyon CA 92679.

5:00–7:00 **Poster Session**

Friday, May 2, 2008
Location: LU Student Union 322

Session: Controlling Runoff Pollution

Chair: John Dorsey, Loyola Marymount University

9:30 **INTRODUCTION TO THE SYMPOSIUM: John Dorsey, L.M.U.**

20 9:40 **COUNTY OF LOS ANGELES COUNTYWIDE STORMWATER/URBAN RUNOFF PUBLIC EDUCATION PROGRAM**
Kimberly Y. Lyman, County of Los Angeles Department of Public Works, Alhambra, CA, 91803.

10:00–10:20 **BREAK**

21 10:20 **PRODUCT SUBSTITUTION: DIAZINON**
G. A. Brosseau. California Stormwater Quality Association (CASQA), P.O. Box 2105, Menlo Park, CA 94026

22 10:40 **USING COMMUNITY BASED SOCIAL MARKETING TO INCREASE USED OIL RECYCLING IN LOS ANGELES**
Joyce Amaro, City of Los Angeles, Stormwater Public Education Program, 2714 Media Center Drive, Los Angeles, CA 90065

23 11:00 **ENFORCEMENT OF WATER WASTING-URBAN RUNOFF CODES & BMPS**
N. Shapiro. City of Santa Monica, Environmental Programs Division, 200 Santa Monica Pier, Suite K, Santa Monica, CA 90401.

11:30–12:30 **Plenary Lecture: LaCorte Hall A-103**

Jon E. Keeley, USGS, Western Ecological Research Center, Sequoia-Kings Canyon Field Station, Three Rivers, CA 93271, USA, and Department of Ecology and Evolutionary Biology, University of California, Los Angeles, CA 90095, USA

9 **"FIRE AS AN ECOSYSTEM PROCESS: PAST, PRESENT AND FUTURE"**

12:30–1:20 **LUNCH BREAK**

24 1:20 **CALTRANS' USE OF AND RESEARCH ON VEGETATED BIOFILTER BMPS**
K.L. Dreher[a] and M.M. Kerner[b]. [a]California Department of Transportation, Division of Environmental Analysis, Sacramento, CA, 94274. [b]California State University – Sacramento, Office of Water Programs, Sacramento, CA, 95819-6025.

25 1:40 **PERFORMANCE OF THE BALLONA FRESHWATER MARSH AS A MULTI-PURPOSE CONSTRUCTED WETLAND.**
Edith Read. E Read and Associates, Inc., Orange, CA, 92866.

26 2:00 **ENFORCEMENT OF WATER WASTING-URBAN RUNOFF CODES & BMPS MEETING THE TRASH TMDL IN THE CITY OF LOS ANGELES**
Morad Sedrak, City of Los Angeles, Bureau of Sanitation, Watershed Protection Division, Los Angeles, CA, 90015.

27 2:20 **SALT CREEK OZONE TREATMENT FACILITY FOR URBAN RUNOFF, DANA POINT, CALIFORNIA**
Brad Fowler, P.E., Director of Public Works & Engineering Services, City of Dana Point, 33282 Golden Lantern, Dana Point, CA 92629

28 2:40 **REUSING ONE'S LOCAL WATER RESOURCES – DRY WEATHER RUNOFF REUSE THE SMURRF WAY**
N. Shapiro. City of Santa Monica, Environmental Programs Division, 200 Santa Monica Pier, Suite K, Santa Monica, CA 90401.

3:00–3:20 **BREAK**

5:00–7:00 **Poster Session**

Friday, May 2, 2008
Location: LU Student Union 326

Session: Reef Biology and Fisheries

Chair: Daniel Pondella II, Occidental College

29 F 8:00 **LIFE HISTORY OF SARGO, *ANISOTREMUS DAVIDSONII*, IN THE SOUTHERN CALIFORNIA BIGHT**
M.C. Mandrup and D.J. Pondella, II, Vantuna Research Group and Department of Biology, Moore Laboratory of Zoology, Occidental College, Los Angeles, CA 90041

30 M 8:20 **MICROSATELLITE DNA ASSESSMENT OF MULTIPLE PATERNITY IN THE VIVPAROUS ROCKFISH *SEBASTES MELANOPS***
K.W. Karageorge and R. Wilson, Jr. Department of Biological Sciences, California State University, Long Beach, Long Beach, CA 90840.

31 8:40 **LONG-TERM POPULATION TRENDS OF SOUTHERN CALIFORNIA SCIAENIDS IN THE PRESENCE OF OCEANOGRAPHIC CHANGE AND POWER PLANT ONCE THROUGH COOLING.**
Eric F. Miller[1], Daniel J. Pondella, II[2], and Kevin T. Herbinson[3]; [1]MBC Applied Environmental Sciences, Costa Mesa, CA; [2]Vantuna Research Group, Occidental College, Los Angeles, CA; [3]ACT Environmental, Inc., Laguna Hills, CA

32 E 9:00 **INVESTIGATING ELK KELP'S (*PELAGOPHYCUS PORRA*), INABILITY TO INVADE POINT LOMA GIANT KELP BEDS**
Stacie M. Fejtek[1], Matthew S. Edwards[1], & Kwan-Young Kim[2] [1]Department of Biology, San Diego State University, San Diego, California, USA [2]Department of Oceanography, Chonnam National University, Gwangju, Korea

33 9:20 **AN EMERGY INPUT ANALYSIS OF SANTA MONICA BAYKEEPER'S KELP RESTORATION PROJECT**
Brian Meux, Santa Monica Baykeeper, Marina del Rey, CA 90292

34 9:40 **SOCIAL-ECOLOGICAL INTERACTIONS IN GIANT KELP FORESTS.**
D. C. Reed, Marine Science Institute, University of California, Santa Barbara, CA. 93106.

10:00–10:20 **BREAK**

35 10:20 **PATTERNS OF FISH AND INVERTEBRATE ASSEMBLAGES AMONG KELP FORESTS IN SAN DIEGO**
P.E. Parnell. Integrative Oceanography Division, Scripps Institution of Oceanography, La Jolla, CA, 92093-0227.

36 F 10:40 **MIDWATER FISH ASSEMBLAGES ASSOCIATED WITH PETROLEUM PLATFORMS ON THE SAN PEDRO SHELF: A COMPARISON WITH ADJACENT NATURAL REEFS**
C. J. B. Martin and C. G. Lowe. Department of Biological Sciences, California State University, Long Beach, CA, 90840.

37 11:00 **THE NEARSHORE ROCKY-REEF FISHES OF THE SOUTHERN CALIFORNIA ISLANDS.**
D.P. Pondella, II. Department of Biology and Vantuna Research Group, Moore Laboratory of Zoology, Occidental College, 1600 Campus Rd. Los Angeles, CA 90041

11:30–12:30 **Plenary Lecture: LaCorte Hall A-103**

Jon E. Keeley, USGS, Western Ecological Research Center, Sequoia-Kings Canyon Field Station, Three Rivers, CA 93271, USA, and Department of Ecology and Evolutionary Biology, University of California, Los Angeles, CA 90095, USA

9 **"FIRE AS AN ECOSYSTEM PROCESS: PAST, PRESENT AND FUTURE"**

12:30–1:20 **LUNCH BREAK**

Friday, May 2, 2008
Location: LU Student Union 326

Session: Advances in Selective Fishing

Chair: Mark Helvey, NOAA

38 1:40 **Overview of Efforts to Reduce Fishery Bycatch**
Mark Helvey, National Marine Fisheries Service

39 2:00 **THE INTERNATIONAL SMART GEAR COMPETITION: INSPIRING INNOVATION BY CAPITALIZING CREATIVITY**
M. Osmond, World Wildlife Fund, Palo Alto, CA 94301

40 2:20 **BOTTOM TRAWL PERFORMANCE IN THE CALIFORNIA HALIBUT TRAWL GROUNDS**
S.P. Wertz, A.J. Frimodig, M.C. Horeczko, T.J. Mason, B.C. Owens, and M.W. Prall. State Fisheries Evaluation Project, Marine Region, California Department of Fish and Game, Los Alamitos, CA, 90720.

41 2:40 **DEVELOPMENTS IN SCIENTIFIC RESEARCH ON THE USE OF MODIFIED FISHING GEAR TO REDUCE LONGLINE BYCATCH OF SEA TURTLES**
Y. Swimmer and C. Boggs. NOAA Fisheries, Pacific Islands Fisheries Science Center, Honolulu, Hawaii 96822

3:00–3:20 **BREAK**

42 3:20 **AN OVERVIEW OF FISHING GEAR AND FISHING PRACTICE MODIFICATIONS THAT HAVE RESULTED IN BYCATCH REDUCTION IN CALIFORNIA'S COMMERCIAL AND RECREATIONAL FISHERIES.**
Angela Louie, California Department of Fish and Game, Los Alamitos, California.

43 3:40 **THE ROLE OF ALLOWABLE FISHING EFFORT IN PROVIDING INCENTIVES TO INNOVATE CONSERVATION TECHNOLOGY**
S. M. Stohs. NOAA Fisheries, Southwest Fisheries Science Center, La Jolla, CA 92037-1508.

44 4:00 **CONSERVATION FISHING AGREEMENT – THE FIRST CONSERVATION EASEMENT IN THE OCEAN?**
Michael Bell, The Nature Conservancy, 75 Higuera Street, Suite 200, San Luis Obispo, CA 93401 Co Presenter: Edwin “Fast Eddie” Ewing, Commercial Fisherman, Morro Bay, CA

45 4:20 **METHODOLOGIES FOR SOCIAL AND GEOGRAPHIC INTEGRATION OF MANDATORY AND VOLUNTARY BYCATCH REDUCTION TECHNOLOGY**
Ana Pitchon, CSU Dominguez Hills, Department of Anthropology, Carson, CA 90747, and Karma Norman, Northwest Fisheries Science Center, Seattle, WA 98112.

5:00–7:00 **Poster Session**

Friday, May 2, 2008
Location: LU Student Union 323

Session: Contributed Papers

46 8:20 **LIFESTYLE AND QUALITY OF HEALTH FOR 19TH CENTURY POPULATIONS IN NORTH AMERICA.**
S. Fitz-González, MFS. California State University, Los Angeles, Department of Anthropology, Los Angeles, CA, 90032.

47 8:40 **TIDAL LOADING RATES FOR FECAL INDICATOR BACTERIA (FIB) IN THE BALLONA WETLANDS, CALIFORNIA: RESULTS OF 12- AND 24-HR SURVEYS**
J. H. Dorsey, **P. M. Carter**, Loyola Marymount University, Department of Natural Science, Los Angeles, CA 90045. Sean Bergquist, Santa Monica Bay Restoration Commission, One LMU Dr., Pereira Annex MS 8160, Los Angeles, CA 90045

48 E 9:00 **FORAGING ECOLOGY OF THE ELEGANT TERN IN RESPONSE TO NEW MARINE HABITAT AT THE RESTORED BOLSA CHICA ECOLOGICAL RESERVE.**
J.N. Hendricks and M.H. Horn. Department of Biological Sciences, California State University Fullerton, CA, 92831.

49 E 9:20 **DEVELOPING *SALICORNIA VIRGINICA* AS A BIO-MONITOR FOR THE HEAVY METALS ZINC AND CADMIUM IN THE BALLONA WETLANDS.**
James R. Holmquist, Philippa M. Drennan, and James Landry. Loyola Marymount University, Departments of Biology and Natural Science, Los Angeles, CA 90045.

50 E 9:40 **THE EFFECTS OF AGE AND SEXUAL EXPERIENCE ON THE MATING SUCCESS OF THE MALE HOUSE CRICKET, *ACHETA DOMESTICUS***
E.S. Peralta and S.E. Walker, Southern California Ecosystems Research Program, California State University, Fullerton, Department of Biological Science, Fullerton, CA, 92831

10:00–10:20 **BREAK**

51 E 10:20 **METAL CONCENTRATIONS IN *MACROCYSTIS PYRIFERA* BETWEEN THREE DEPTHS AT LA HARBOR AND EAGLE ROCK**
M.R. Raith and A.Z. Mason, Manley Lab Group, CSU, Fullerton and CSU, Long Beach, Department of Natural Sciences and Mathematics, Long Beach, CA, 90840.

52 E 10:40 **SETTLEMENT OF *OSTREA CONCHAPHILA* AS A FUNCTYION OF TIDAL HEIGHT IN A SOUTHERN CALIFORNIA**
L.A. Sam and D.C. Zacherl. California State University, Fullerton. Department of Biological Science.

53 E 11:00 **SONG PLAYBACK EXPERIMENTS IN ANNA'S AND COSTA'S HUMMINGBIRDS.**
B.R. Williams, C. Castro, and A.M. Houtman. California State University, Fullerton, Department of Biology, Fullerton, CA, 92831.

11:30–12:30 **Plenary Lecture: LaCorte Hall A-103**

Jon E. Keeley, USGS, Western Ecological Research Center, Sequoia-Kings Canyon Field Station, Three Rivers, CA 93271, USA, and Department of Ecology and Evolutionary Biology, University of California, Los Angeles, CA 90095, USA

9 **"FIRE AS AN ECOSYSTEM PROCESS: PAST, PRESENT AND FUTURE"**

12:30–1:20 **LUNCH BREAK**

Friday, May 2, 2008
Location: LU Student Union 323

Session: Contributed Papers (Continued)

54 1:20 **LASER ABLATION ICP-MS ANALYSIS OF PREHISTORIC AND CONTEMPORARY WHITE CROAKER (*Genyonemeus lineatus*) OTOLITHS**
James F. Harwood California State University, Bakersfield, Department of Biology, Bakersfield, CA 93311

55 1:40 **VARIATION IN THE DEEP SEA HOLOTHURIAN *PSYCHROPOTES LONGICAUDA* AND CONFIRMATION OF THE SPECIES *PSYCHROPOTES MIRABILIS***
K.D. Trego, Nautilus Oceanic Institute, La Jolla, CA 92037

56 2:00 **ECOSYSTEM IMPLANTATION ON SATURN'S MOON TITAN BY ACCUMULATION OF INTERNAL OCEAN SATELLITE ICE DEBRIS CONTAINING ORGANISMS**
K.D. Trego, Nautilus Oceanic Institute, La Jolla, CA 92037

57 2:40 **TRANSIENT MACROFAUNA INVERTEBRATES IN THE CHALLENGER DEEP ECOSYSTEM OF THE MARIANAS TRENCH**
K.D. Trego, Nautilus Oceanic Institute, La Jolla, CA 92037

3:00–3:20 **BREAK**

Friday, May 2, 2008
Location: LU Student Union 323

Session: Vulcanology

Chair: A.L Smith, CSU San Bernardino

58 3:20 **THE GENERATION OF QUENCHED ENCLAVES DURING MAGMA MINGLING OF MAFIC MAGMAS: EXAMPLES FROM THE SIERRA NEVADA AND THE SOUTHERN CASCADES**
B.L. Browne, A. Steiner, M. Van Ry and P. Saleen Cal State Fullerton Department of Geological Sciences, Fullerton, CA, 92834

59 3:40 **TURONIAN TO CAMPANIAN LAVAS FROM SOUTHWEST PUERTO RICO AND THE TIREO GROUP OF SOUTH CENTRAL HISPANIOLA (GREATER ANTILLES ISLAND ARC): IDENTIFICATION OF AN UPPER CRETACEOUS ISLAND ARC**
Johannes H. Schellekens[1], and Wayne T. Jolly[2] [1]temporarily Dept. of Geological Sciences, California State University, San Bernardino CA, [2]Department of Geological Sciences, Brock University, St. Catharines, Ontario L2O 3A1

60 P 4:00 **GRANDE SOUFRIERE HILLS VOLCANO, DOMINICA, LESSER ANTILLES**
G.E. Daly[1], A.L. Smith[1], M.J. Roobol[2], and J.E. Fryxell[1] [1]Department of Geological Sciences, California State University, San Bernardino, CA 92407; [2]Saudi Geological Survey, Jeddah, Saudi Arabia

61 P 4:20 **A STUDY OF GEOTHERMAL SPRINGS IN NORTHERN DOMINICA.**
S. Harrell, A.L. Smith, E. Melchiorre, J. E. Fryxell, Department of Geological Sciences California State University, San Bernardino, California, 92407

62 4:40 **GEOLOGICAL EVOLUTION OF DOMINICA, LESSER ANTILLES**
A L. Smith[1], M.J. Roobol [2], J.E. Fryxell[1] and L. Fernandez[1] [1]Department of Geological Sciences, California State University, San Bernardino, CA [2]Saudi Geological Survey, Jeddah, Saudi Arabia

5:00–7:00 **Poster Session**

Friday, May 2, 2008
Location: Ballroom

Session: Poster Session

63 E **GENETIC VARIATION AND SYSTEMATIC DIVERSITY IN THE AMPHIPOD GENUS *CYAMUS*, USING MITOCHONDRIAL AND NUCLEAR GENE SEQUENCE ANALYSIS.**
Tishy-Linda M. Bunk, Biological Sciences, Cal. State L.A. Los Angeles, CA 90032-8201

64 **GENETIC CONFIRMATION OF HYBRIDIZATION BETWEEN *CATOSTOMUS FUMEIVENTRIS* AND *CATOSTOMUS SANTAANAE* (CYPRINIFORMES: CATOSTIMIDAE) IN THE SANTA CLARA DRAINAGE.**
D.G. Buth[1], J. Sim[1], and C.C. Swift[2]. [1]Dept. of Ecology and Evolutionary Biology, UCLA, Los Angeles, CA 90095-1606, and [2]ENTRIX, Inc., 2140 Eastman Avenue, Suite 200, Ventura, CA 93003.

65 E **OBSERVING THE EFFECTS BIOFILMS, PLANTS AND SEDIMENTS HAVE ON CONCENTRATIONS OF NITRATE AND PHOSPHATE IN WATER SUPPLIES.**
John Campo and Genevieve Ryan. Pasadena City College, Sustainability Studies Research Group, Pasadena, CA, 91106.

66 **COYOTE AND FOX ON THE PALOS VERDES PENINSULA**
Dalkey, A[1], K. Gallagher[2], K. Bailey[3], Elaine Chow[3], K. Lyberger[3], B. Niemiec[4], and N. Wakayama[3]. [1]Palos Verdes Peninsula Land Conservancy, 916 Silver Spur Road #207, Rolling Hills Estates, CA, 90274, [2]Biology Department, California State University Long Beach, Long Beach, CA, 90840 [3]Palos Verdes Peninsula High School Rolling Hills Estates, CA, 90274, [4]Chadwick School, Palos Verdes, CA, 90274.

67 E **ABOVE AND BELOWGROUND FEEDBACKS FOLLOWING EXOTIC PLANT INVASION AND RESTORATION OF COASTAL SAGE SCRUB OF SOUTHERN CALIFORNIA**
S.J.M. Dickens and E.B. Allen, Department of Botany and Plant Sciences, University of California Riverside, Riverside CA 92521

68 E **THE EFFECTS OF NITROGEN ADDITION AT DIFFERENT STAGES OF DECOMPOSITION**
M. Greas, D. LeBauer, and K. Treseder. University of California, Irvine, Department of Ecology and Evolutionary Biology, Irvine, CA, 92697.

69 **PROTOCOLS FOR *HALIOTIS RUFESCENS* EGG CRYOPRESERVATION AND *IN VITRO* FERTILIZATION (YEAR 2)**
Julie A. Guerin. Cabrillo Marine Aquarium, San Pedro, CA 90731; Palos Verdes Peninsula High School, Rolling Hills Estates, CA 90274

70 E **THE EFFECTS OF DISTURBANCE OF BIOLOGICAL SOIL CRUSTS ON THE GERMINATION OF EXOTIC PLANTS IN COASTAL SAGE SCRUB.**
Rebecca R. Hernandez and Darren Sanduist, Department of Biological Science, California State University, Fullerton, CA 92831.

71 **ETHYLENE, TEMPERATURE, AND LIGHT EFFECTS ON THE GERMINATION OF THE SAND VERBENA, *ABRONIA MARITIMA* S. WATSON.**
Kristine Tulio, Noel De Leon, and Philippa M. Drennan. Loyola Marymount University, Department of Biology, Los Angeles, CA 90045.

72 E **EFFECTS OF SMALL-SCALE DISTURBANCE ON SEED BANK SPECIES IN A COASTAL SAGE SCRUB COMMUNITY**
F.D. Herrera. Biological Sciences Department, California State Polytechnic University, Pomona, CA, 91768

73 E **EFFECTS OF LIGHT AND COLUMN HEIGHT ON DIEL VERTICAL MIGRATION OF THE MARINE GASTROPOD *KELLETIA KELLETII***
Kelley, S.L., Cortez, C.J., Hoese, W.J. and Zacherl, D.C.;California State University, Fullerton Department of Biological Science, Fullerton, CA 92831

74 E **PLANT ABSORPTION OF THE CHEMICAL POLLUTANTS NITRATE AND AMMONIA**
Niree Kodaverdian, Pwint Khine, Steven Do, Jason Diep, Jimmy Lau, Kyaw Lynn. Sustainability Studies Research Group, Pasadena City College, CA 91106.

75 **USING HISTORICAL TAGGING DATA (1962-1971) TO ANALYZE THE SPAWNING RELATED MOVEMENTS OF BARRED SAND BASS, *PARALABRAX NEBULIFER* (SERRANIDAE) IN SOUTHERN CALIFORNIA.**
C. Linardich, E. T. Jarvis, C. F. Valle, and P.Young. California Department of Fish and Game, Marine Region, Los Alamitos, CA, 90702.

76 E **POST-FIRE PLANT SUCCESSION AT TUCKER WILDLIFE SANCTUARY IN MODJESKA CANYON, CALIFORNIA.**
V. Lopez, S. Simjee, W.J. Hoese, and D.R. Sandquist. Department of Biological Science, California State University Fullerton, Fullerton, CA 92834.

77 E **QUESTION REALITY: QUALITATIVE INTERPRETATIONS OF UNIVERSAL SCALING LAWS IN BIOLOGY-ECOLOGY-EVOLUTION**
V.G. Minnich. M.L. Droser Advisor. Department of Earth Sciences. University of California, Riverside, 92521.

78 P **PALEO GROUNDWATER CHEMISTRY RECORD FROM FAULT ZONE BANDED CALCITE, MOUNTAIN PASS MINE, CA**
D.S. Montgomery and E.B. Melchiorre. California State University, Department of Geology, San Bernardino, CA, 92407.

79 E **EFFECTS OF ANTHROPOGENIC WATER INPUTS ON ARGENTINE ANT INVASION IN RIPARIAN AREAS OF SOUTHERN ORANGE COUNTY**
Kimberly Nelson and Paul Stapp, California State University of Fullerton Department of Biological Science, Fullerton, CA, 92831

80 E **BIOLOGICAL DIVERSITY STUDY OF ARTHROPODS AT SELECTED SITES IN THE HAHAMONGHA WATERSHED PARK, PASADENA, CA**
Alice Okumura, Pasadena City College, Pasadena, California

82 E **GENETIC DIVERSITY ANALYSIS OF THE CALIFORNIA INVASIVE CHAMELEON GOBY (*TRIDENTIGER TRIGONOCEPHALUS*); EXPLORATON OF A GENETIC BOTTLENECK WITH COMMENTS ON AN *IN SITU* RISE IN POPULATION**
J.R. Radecki, R.R. Wilson. California State University at Long Beach, Department of Biological Sciences, Long Beach, CA, 90840.

83 E **GENETIC VARIABILITY WITHIN THE SANTA ANA WOOLLY STAR, *ERIASTRUM DENSIFOLIUM* SSP. *SANCTORUM*: REANALYSIS SEVENTEEN YEARS LATER**
Y. Sanchez, A. Cohen, and Y. Atallah. California State University, Fullerton, Department of Biological Science, Fullerton CA, 92831.

84 P **SELENIUM STRATIFICATION AND MIXING DYNAMICS OF UPPER NEWPORT BAY, CALIFORNIA**
Shelley Shaul, Rachel Andrus, Roxanna Aguirre-Robertson, Barry Hibbs, Center for Environmental Analysis (CEA-CREST) California State University, Los Angeles, 90032

86 E **A COMPARISON OF EMBOLISM AND EMBOLISM REPAIR IN TWO SALVIA SPECIES.**
L.M. Velasco and H.J. Schenk. Southern California Ecosystems Research Program, California State University, Fullerton, Department of Biology, 800 N. State College Blvd. Fullerton CA 92831

87 E **THE LIGHT'S ON BUT NOBODY'S HOME: NEGATIVE PHOTOTACTIC RESPONSE OF *KELLETIA KELLETII* LARVAE TO LIGHT INTENSITY AND WAVELENGTH.**
K.M. Walker, W.J. Hoese, and D.C. Zacherl, California State University Fullerton, Department of Biological Science, Fullerton, CA, 92834.

88 **PREDICTING LUNG CANCER RELAPSE USING LEVELS OF 2881 PROTEINS**
Timothy Wu[1], Dennis Kibler[2]; [1]stormfyre@sbcglobal.net, University High School, 4771 Campus Drive, Irvine, CA 92612; [2]dennis.kibler@gmail.com, University of California, Irvine, Irvine, CA 92697

89 **COMPARISON BETWEEN ALCOHOLIC AND NONALCOHOLIC LIVER USING CT PHANTOM CALIBRATION**
Wu, Helena(Hao). Los Angeles Biomedical Research Institute, Harbor UCLA, St. John's Department of Cardiovascular Research.

Saturday, May 3, 2008
Location: LU Student Union 324

Session: Culture and Environment in the American Tropics

Chair: Janine Gasco, CSU Dominguez Hills

90 8:40 **TRADITIONAL AGROFORESTRY SYSTEMS IN THE SOCONUSCO REGION OF CHIAPAS, MEXICO**
J.L. Gasco, California State University, Dominguez Hills, Dept. of Anthropology, Carson, CA 90747

91 9:00 **LAND MANAGEMENT IN COASTAL CHIAPAS**
T. Kasper, J. Lewis, E. Smith, S. Reimann, California State University, Dominguez Hills, Dept. of Anthropology, Carson, CA 90747

92 9:20 ***PANELA* PRODUCTION IN MESOAMERICA**
S. Ulrich, California State University, Dominguez Hills, Dept. of Anthropology, Carson, CA 90747

93 9:40 **THE PROYECTO ARQUEOLOGICO TUMBES: AN OVERVIEW TO THE RESEARCH PROJECT**
J.D. Moore, California State University, Dominguez Hills, Dept. of Anthropology, Carson, CA 90747

94 10:00 **THE 2007 FIELD SEASON OF PROYECTO ARQUEOLOGICO TUMBES**
C. D'Anna and T. Black, California State University, Dominguez Hills, Dept. of Anthropology, Carson, CA 90747

95 10:20 **PREHISTORIC DIACHRONIC VARIATION IN MOLLUSCAN ASSEMBLAGES AND PALEOCLIMATIC DISRUPTIONS IN FAR NORTHERN PERU**
J.D. Moore and J. Lewis, California State University, Dominguez Hills, Dept. of Anthropology, Carson, CA 90747

10:40–11:00 **BREAK**

11:00–11:20 **Welcome, Student Grant Awards,**

11:30–12:30 **Plenary Lecture: LU Student Union 324**

Bill Hamner: UCLA, Dept of Ecology and Evolutionary Biology

"INNER SPACE SPECIATION PROJECT: MID-WATER AND EPIBENTHIC SAMPLING IN THE CELEBES SEA, PHILIPPINES"

12:30–1:20 **LUNCH BREAK**

Saturday, May 3, 2008
Location: LU Student Union 324

Session: Contributed Papers

Chair: Philippa Drennan, Loyola Marymount University

96 1:40 **JOSHUA TREE (*YUCCA BREVIFOLIA*) MORTALITY AND RESPROUTING FOLLOWING THE 2005 HACKBERRY COMPLEX FIRES IN THE MOJAVE DESERT.**
Philippa M. Drennan and John P. Waggoner, III. Department of Biology, Loyola Marymount University, Los Angeles, CA, 90045.

97 E 2:00 **INFLUENCE OF ANTHROPOGENIC NOISE ON SONG STRUCTURE IN *CALYPTE* HUMMINGBIRDS**
English, S. and Houtman, A. California State University Fullerton, Department of Biological Science, Fullerton, CA, 92831.

98 E 2:20 **ARE LOOKS DECEIVING? SHOULD TWO NEARLY IDENTICAL CHITONS REALLY BELONG IN DIFFERENT SUBGENERA?**
V.H. Lee[1], A.A. Fore[1], R.Z. El Hajjaoui[1], A. Draeger[2], and D.J. Eernisse[1]. [1]California State University Fullerton, Department of Biological Science, Fullerton, CA 92834, and [2]Kensington, California.

99 E 2:40 **EVIDENCE FOR 'CONTEXTUAL DECISION HIERARCHIES' IN THE HERMIT CRAB, *PAGURUS SAMUELIS*.**
Billock, W.L. and Dunbar, S.G. Department of Earth and Biological Sciences, Loma Linda University, Loma Linda, California, USA 92350.

3:00–3;20 **BREAK**

100 E 3:20 **EFFECTS OF PREDATOR DENSITY ON GROWTH AND SURVIVAL OF THE TEMPERATE REEF FISH *LYTHRYPNUS DALLI***
J.M. Krug[1], S. Painter[2] and M.A. Steele[1]. [1]California State University, Northridge, Department of Biology, Northridge, CA, 91330; [2]University of California, Los Angeles, Department of Ecology and Evolutionary Biology, Los Angeles, CA, 90024.

101 E 3:40 **PHYLOGEOGRAPHIC ANALYSIS OF THE FIDDLER CRAB *UCA PRINCEPS* IN THE GULF OF CALIFORNIA AND OUTER COAST OF BAJA CALIFORNIA.**
M. Kodama, R. A. Ellingson and D. K. Jacobs. University of California, Los Angeles, Department of Ecology and Evolutionary Biology, Los Angeles, CA, 90095.

102 P **4:00** **MOBILITY OF SELENIUM AND NITRATE ALONG A SHALLOW GROUNDWATER FLOWPATH, ORANGE COUNTY, CALIFORNIA**
Rachel Andrus, Shelley Shaul, Barry Hibbs, Center for Environmental Analysis (CEA-CREST) California State University, Los Angeles, 90032 Andre Ellis, Department of Geology, University of Texas- El Paso, TX, 79968

103 F **4:20** **GENETIC SEPARATION FOR THE OUTER SOUTHERN CALIFORNIA CHANNEL ISLANDS? MICROSATELLITE DATA FROM KELP BASS (*PARALABRAX CLATHRATUS*)**
S.M. Trbovich and R.R. Wilson. California State University-Long Beach, Department of Biological Sciences, Long Beach, CA 90840

Saturday, May 3, 2008
Location: LU Student Union 322

Session: Research Training Program

Chair: Gloria Takahashi:

104 **8:40** **IDENTIFYING MACHINE LEARNING ALGORITHMS THAT POSESSESS HIGH PREDICTIVE ACCURACIES FOR MULTIPLE TYPES OF CANCER**
Timothy Wu[1], Dennis Kibler[2]; [1]stormfyre@sbcglobal.net, University High School, 4771 Campus Drive, Irvine, CA 92612; [2]dennis.kibler@gmail.com, University of California, Irvine, Bren School of Information and Computer Science, Computer Science Department, Irvine, CA 92697

105 **9:00** **PROTEASE INHIBITORS IN AUGMENT TEMOZOLOMIDE-BASED TREATMENT FOR MALIGANT GLIOMAS**
J.J. Wang, W.J. Wang, and T.C. Chen, Department of Neurosurgery, University of Southern California, Los Angeles, 90033

106 **9:20** **REGULATION OF ALDEHYDE OXIDASE *4 (Aox4)* GENE BY THE GRAINY-HEAD-LIKE EPITHELIAL TRANSACTIVATOR (Get1) TRANSCRIPTION FACTOR**
A. Venkatesh, A. Bhandari, and B. Andersen. Departments of Medicine and Biological Chemistry, University of California, Irvine, CA, 92697.

107 **9:40** **CARBOHYDRATE-BASED EXPERIMENTAL THERAPEUTICS FOR CANCER, HIV/AIDS AND OTHER DISEASES**
Sarine Shahmirian and Steven B. Oppenheimer. California State University Northridge, Department of Biology and Center for Cancer and Developmental Biology, Northridge, CA, 91330.

108 **10:00** **TO SPECIATE OR NOT TO SPECIATE?: POPULATION STRUCTURE OF *HAMINOEA VESICULA* (OPISTHOBRANCHIA: HAMINOEIDAE) IN THE NORTHEAST PACIFIC**
Bonnie R. Lei. Walnut High School, 400 North Pierre Road, Walnut, CA 91789. Department of Biological Sciences, California State Polytechnic University, Pomona, 3801 West Temple Avenue, Pomona, CA 91768-4032.

109 **10:20** **SURVEY OF THE PLEISTOCENE CAMELIDAE MATERIAL OF RALPH B. CLARK REGIONAL PARK INTERPRETIVE CENTER, ORANGE COUNTY, CA.**
M.K. Crowe and L. Babilonia Ralph B. Clark Regional Park, Interpretive Center, 8800 Rosecrans Ave. Buena Park, CA 90621.

10:40–11:00 **BREAK**

11:00–11:20 **Welcome, Student Grant Awards,**

11:30–12:30 **Plenary Lecture: LU Student Union 324**

Bill Hamner: UCLA, Dept of Ecology and Evolutionary Biology

"INNER SPACE SPECIATION PROJECT: MID-WATER AND EPIBENTHIC SAMPLING IN THE CELEBES SEA, PHILIPPINES"

12:30–1:20 LUNCH BREAK

Saturday, May 3, 2008
Location; : LU Student Union 322

Session: Research Training Program (Continued)

Chair: Jonathan Baskin, Cal. Polytechnic University, Pomona

110 1:20 COMPARISON BETWEEN ALCOHOLIC AND NORMAL LIVER USING CT PHANTOM CALIBRATION
Wu, Helena (Hao), Palos Verdes Peninsula H.S.

111 1:40 EVOLUTIONARY CHANGES IN THE DIGESTIVE TRACT OF THE PARASITIC CATFISHES (TRICHOMYCTERIDAE)
Jonathan N. Baskin[1], **Brian Diep**[2], Jason Hwan[1], Diana Jeon[1].California State Polytechnic University Pomona, Department of Biological Sciences, Pomona, CA, 91768[1], San Gabriel High School, San Gabriel, CA, 91776[2]

112 2:00 MODELING THE TOXIC EFFECTS OF SILVER NANOPARTICLES UNDER VARYING ENVIRONMENTAL CONDITIONS
Joyce Chai Palos Verdes Peninsula High School, Rolling Hills Estates, CA Mentor: Professor Eric M.V. Hoek, UCLA Department of Civil and Environmental Engineering.

113 2:20 CHEMOTHERAPY AND THE UNFOLDED PROTEIN RESPONSE
Kevin Pan (Lynbrook High School) Dr. Albert C. Koong, PhD & Mike Olson, M.D. Department of Radiation Oncology, Stanford University

114 2:40 THE ROLE OF THE GET1 TRANSACTIVATOR IN THE REGULATION OF EPITHELIAL BARRIER STRUCTURE AND FUNCTION IN BLADDER EPITHELIUM
T. Kwong, A. Soto, and B. Andersen. Chao Cancer Laboratory, University of California Irvine, Department of Medicine, Irvine, CA, 92697

3:00–3:20 BREAK

Saturday, May 3, 2008
Location: LU Student Union 322

Session: Research Training Program and Endangered Species

Chair: Ann Dalkey, Palos Verdes Peninsula Land Conservancy

115 3:20 THE EL SEGUNDO BLUE BUTTERFLY RETURNS TO SOUTH BAY BEACHES
A. Dalkey[1] and **M. Acosta**[2]. [1]Palos Verdes Peninsula Land Conservancy, 916 Silver Spur Road #207, Rolling Hills Estates, CA 90274, [2]SEA Lab, 1021 North Harbor Drive, Redondo Beach, CA. 90277.

116 3:40 EFFECTS OF VARYING ZINC CONCENTRATIONS ON BIOLUMINESCENCE IN *CYPRIDINA HILGENDORFII*
Debra Chang, Rancho Palos Verdes Peninsula H.S.

117 4:00 **THE ECOLOGY OF COYOTES ON THE PALOS VERDES PENINSULA**
Rebecca Niemiec[1] Chadwick High School, 26800 South Academy Drive Palos Verdes, CA 90274; Ann Dalkey, Palos Verdes Peninsula Land Conservancy 916 Silver Spur Road #207, Rolling Hills Estate, CA 90274; Dr. Paul Stapp, Department of Biological Science, California State University, Fullerton PO Box 6850, Fullerton, CA 92834

118 4:20 **GENETIC COMPONENT IN MINIATURE SIZE MUTATION OF THE ENDANGERED PALOS VERDES BLUE BUTTERFLY**
E. Yang[1] and J. Johnson[2]. [1]Palos Verdes Peninsula High School, 27118 Silver Spur Road, Rolling Hills Estates, CA 90274, [2]The Urban Wildlands Group, Los Angeles, CA 90024-0020

ADDITIONAL TALKS

119 **STUDY OF THE TRUNCATION OF CONVEX SYMMETRICAL POLYHEDRA**
Brian Li, Chadwick School

120 **ACHIEVING NUTRIENT REDUCTIONS IN THE NEWPORT BAY WATERSHED – A CASE HISTORY**
C.P. Crompton and K.H. Cowan. County of Orange, OC Watersheds Program, Anaheim, CA, 92806

Abstracts, in Program Order

1. IMPACTS OF POST-FIRE GEOLOGICAL PROCESSES ON AMPHIBIAN AND FISH HABITAT IN SOUTHERN CALIFORNIA

R.N. Fisher, A.R. Backlin, C.J. Rochester, and S.H. Cannon. USGS Western Ecological Research Center, San Diego, CA, rfisher@usgs.gov, abacklin@usgs.gov, crochester@usgs.gov; USGS Central Region Geologic Hazards Team, Denver, CO, cannon@usgs.gov

Fall firestorms in southern California are becoming more common and the burn areas often now include entire watersheds. Several amphibians and fish in southern California are very rare or almost extirpated and they may have localized populations within specific watersheds. USGS has been developing a series of predictive models to predict the volume and probability of debris flows following burns as tools for reducing risk to life and property under various precipitation scenarios. We evaluate these models as they relate to amphibian and fish habitat and document the physical processes that take place following watershed burning from our recent observations. We also discuss recent data about ash from the 2007 firestorms as it potentially relates to distributional patterns observed in salamanders following the 2003 firestorms. Active management through extreme measures may be required in some instances to salvage populations until ecological resilience is restored in the southern California landscape.

2. IMPACTS OF FIRE ON SANTA ANA SPECKLED DACE: A REDUCTION OF POPULATION AND GENETIC BIODIVERSITY IN SOUTHERN CALIFORNIA

A.E. Metcalf, P. VanMeter, and J. VanMeter. Dept. of Biology, California State University, San Bernardino, 5500 University Pkwy, San Bernardino, CA 92407

Southern California is increasingly recognized as a biodiversity hotspot with high levels of endemism and population fragmentation. As such, this region is sensitive to the potential significant loss of biodiversity from impacts such as severe fire and flood. The massive Fall 2003 wildfires in southern California burned five sub-watersheds of the Santa Ana River watershed to varying degrees, ranging from 95% to 12% loss of vegetation. Extensive flooding during the 2003–2004 winter followed this fire event. The Southern California Freshwater Fauna Working Group found that the combination of fire followed by flooding caused the extirpation of Speckled Dace populations from the two streams that had the most watershed burned. Here, we report that those lost populations have not recovered and that this has resulted in a loss of biodiversity. Our genetic analysis of mtDNA sequence variation strongly suggest that Santa Ana Speckled Dace is a genetically distinct group of the more geographically widespread *Rhinichthys osculus*; and, that Santa Ana Speckled Dace have been impacted by the local extinctions of two of the five stream populations. Our more intensive investigation of genetic structure within and among Santa Ana Speckled Dace populations is still in progress, yet preliminary results suggest population structure and genetic diversity were adversely affected by the events precipitated by the 2003 wildfires resulting in a reduction of southern California biodiversity.

3. ARTHROPOD RECOLONIZATION AFTER DISTURBANCE BY FIRE: THE IMPORTANCE OF LOCAL VS. LANDSCAPE PROCESSES

R.A. Redak, J.C. Burger. Department of Entomology, John T. Rotenberry, Department of Biology, University of California, Riverside, 92521 and M.A. Patten, Oklahoma Biological Survey, Norman Oklahoma 73019

Natural lands are increasingly being impacted by habitat fragmentation, invasive species establishment, and altered disturbance regimes. Both the speed and direction of community succession are likely to change with these local and landscape-level changes. In order to predict how arthropod assemblages may change in light of anthropogenic pressures, we need to better understand the relative importance of these

processes. We compared arthropod communities in southern California coastal sage scrub in burned and nearby unburned sites with respect to local and landscape-scale vegetation and geography to infer whether (i) local survival and biotic interactions or (ii) immigration from the surrounding landscape is more important in organizing communities recovering after fire.

Our results indicate that ground dwelling insects were associated with local features and were shared across burning treatments. These species may recover quickly from light disturbance by surviving and reproducing and be initially, but not ultimately, resilient to the effects of fragmentation. Plant dwelling insects were associated with landscape features, but only weakly correlated with local features and not highly shared across burn treatments. Local biotic interactions (e.g., predation and competition) as well as immigration may explain their patterns of occurrence. Mobile arthropods were correlated with landscape features and were shared across sites. Habitat fragmentation and disturbance (i.e., fire) intensity should strongly affect direction and rate of community recovery by affecting both immigration and local survival of arthropods. Local changes, such as non-native grass invasion, should affect less mobile arthropods by increasing intensity of periodic fires and altering local vegetation structure.

4. A SHORT-TERM EVALUATION OF A LONG-TERM RESEARCH PROBLEM: DESERT TORTOISES, THEIR HABITATS AND FIRE

T.C. Esque, K. Drake, L.A. DeFalco, K.E. Nussear, S. Scoles-Sciulla, and P.A. Medica. US Geological Survey, Western Ecological Research Center, 160 N. Stephanie St., Henderson, Nevada 89074

In the Mojave Desert, tortoises (*Gopherus agassizii*) inhabit shrub communities that were invaded by Mediterranean annual grasses and carry fires that modify vegetation structure and composition. Although the immediate effect of fires on desert tortoises have been established as detrimental, it is still unknown how and if tortoises use large burned areas. We hypothesized that tortoises living near burned edges would use both burned and unburned habitats differentially for food and cover in comparison to animals living solely in burned or unburned sites. The Southern Nevada Fire Complex burned more than 32,000 acres of designated desert tortoise Critical Habitat in 2005. In 2006 we initiated a study to understand if re-seeding habitat with native plants could benefit desert tortoises, and how tortoises responded to the habitat modifications brought about by fire and restoration activities. To accelerate the recovery of food and cover plants for desert tortoises, we established monitoring plots (n=51) within this fire complex to evaluate multiple treatments (seeded burn, unseeded burned and unburned). Some establishment of seeded species occurred on most experimental sites. Simultaneously, we initiated studies to quantify desert tortoise use of burned and unburned areas in proximity to the restoration treatments by comparing the spatial distribution, movements, site fidelity, gender distribution, and condition of tortoises in burned and unburned areas.

5E. EFFECTS OF FIRE ON RODENTS IN SAGEBRUSH-JUNIPER HABITATS OF THE MOJAVE DESERT

C.M. Moore and P. Stapp. California State University, Fullerton, Department of Biological Science, Fullerton, CA, 92831

Fire can severely affect desert rodents, directly through mortality, and indirectly, by altering habitat and food resources. Few studies have examined changes in rodent communities following fires in North American dry deserts because fires tend to be infrequent. We investigated the effects of the 2005 Hackberry Complex Fire on rodents in sagebrush-juniper habitats at high elevations in the Mojave National Preserve. For two summers after the fire, we live-trapped rodents across the boundary between burned and unburned areas to determine how different species responded to fire. We also examined foraging in artificial seed trays during full and new moon phases to investigate potential differences in rates of granivory across the burned-unburned transition. Kangaroo rats (*Dipodomys* spp.) were the most abundant rodents remaining in burned areas (88–98% of individuals), whereas cricetid rodents (*Peromyscus* spp.) tended to be restricted to unburned vegetation. In 2006, seed removal rates were much higher on new than on full-moon nights, and decreased with distance from the unburned edge, suggesting that rodents were sensitive to predation risk in the open. However, this difference disappeared in 2007, when seed removal rates were high (>75–95% of seeds) regardless of distance from the edge, and on both full- and new-moon nights. We speculate that rodents foraged more on risky, full-moon nights in 2007 because fewer natural seeds were available during the recent drought. Our results demonstrate the large effects of fire on rodent communities, and suggest how granivorous rodents may affect plant recovery via their foraging activity.

6. ACTIVE MANAGEMENT AIDS RECOVERY OF BURNT NATURAL LANDSCAPES

Carl E. Bell. Regional Advisor – Invasive Plants, University of California Cooperative Extension, San Diego, CA 92123

Large tracts of open space have been acquired throughout southern California by public agencies and private organizations over the past few years. Much of this land has become critical elements in Habitat Conservation Plans (HCP). These HCP's are designed to provide high quality, functional ecosystems that preserve and promote native flora and fauna, especially listed threatened and endangered species. Unfortunately, many of these properties are degraded from decades of grazing and human impacts. In addition, much of this land was burnt in the wildfires of 2003 and 2007. HCP goals will not likely be realized if the land is not successfully restored to the natural ecosystems that previously existed. Active management of these properties is needed to get control of non-native vegetation and to encourage the growth of the native flora. However, the available literature does not provide guidance in selecting appropriate restoration practices for the particular ecosystems of southern California, especially in post-wildfire situations. Research is being conducted to compare alternative restoration practices on several sites. The primary goal is to generate scientifically based methods, tactics, and strategies that can be used by land managers within public and private organizations to guide them in restoring degraded or burnt landscapes and achieving the goals of the HCP's.

Co-investigators and cooperators for this research include; Edith Allen, UCR; Marti Witter and Christy Bingham, National Park Service; John Ekhoff and Tim Dillingham, CA Department of Fish and Game; Maeve Handley and Jeremy Buegge, County of San Diego.

7. SUSTAINABLE AND FIRE-SAFE LANDSCAPES

Sabrina Drill. UC Cooperative Extension - Los Angeles County, 4800 E. Cesar E. Chavez Ave., Los Angeles, CA 90022

What are sustainable and fire-safe landscapes, and how can we find, create, and/or maintain them? In 2004, we began the Sustainable and Fire Safe (SAFE) Landscapes extension program to simultaneously improve fire preparation for wildland/urban interface (WUI) residents, AND encourage WUI residents to be better stewards of neighboring habitat. We looked at the interaction between managing landscapes to reduce the threat from fire, and the loss of native vegetation and increase in invasive vegetation. Specifically, we examined situations where the introduction of invasive plants to WUI yards and subsequent escape to wildlands might be a direct result of recommendations for fire-safe plant choices. Several invasive plants, such as invasive iceplants, myoporum, periwinkle, and ivys, are often touted as fire safe plants, with very little evidence to support this. We notified those developing and extending plant lists about the ecological impacts of invasive species and encouraged them to revise their lists. We also developed an extension publication, the 2008 SAFE Landscapes Calendar and Guidebook, that educates homeowners about invasive plants and fire-safe landscaping simultaneously (available at http://ucanr.org/safelandscapes). Another pressing issue affecting habitat in the WUI is brush clearance, or vegetation management beyond the landscaped areas. Currently we are working with a wide variety of stakeholders to bring clarity about the science behind fuel reduction and what is required by agencies to a specific area, the western portion of the Santa Monica Mountains in Los Angeles County.

8. CHAPARRAL DOES NOT "NEED" TO BURN: CORRECTING FIRE ECOLOGY MYTHS ABOUT MEDITERRANEAN SHRUBLANDS

Richard W. Halsey, Director, California Chaparral Institute, PO Box 545, Escondido, CA 92033

The push to return fire to natural plant communities has led to an overly broad, misapplication of the fire suppression/fuel build-up model. This is especially true for chaparral ecosystems in Southern California where anthropogenic fires have dramatically increased fire frequency leading to the extirpation of chaparral in many areas. Chaparral is continually described in media reports as "over-grown" or "unnaturally" dense and is seen by many fire and land managers as a system that "needs" to burn. Such perspectives are value laden and do not reflect sound, ecological principles. Tools designed to study fire in forested systems, such as fire severity mapping and fire behavior models, are not easily used in chaparral systems. In conjunction with misunderstanding chaparral crown-fire regimes and seeing chaparral as only a "fuel" rather than a dynamic native ecosystem, the misapplication of "forest-based" research methods can lead to inaccurate conclusions and inappropriate land use policies concerning California shrublands.

9. FIRE AS AN ECOSYSTEM PROCESS: PAST, PRESENT AND FUTURE

Jon E. Keeley. USGS, Western Ecological Research Center, Sequoia-Kings Canyon Field Station, Three Rivers, CA 93271, USA, and Department of Ecology and Evolutionary Biology, University of California, Los Angeles, CA 90095, USA

A global view of potential vs actual vegetation distribution leads to the inescapable conclusion that fire is a major driver of ecosystem distribution and from the paleo-record it is apparent it has been a factor since the earliest origins of land plants. Fire-prone ecosystems are dependent on patterns of primary productivity, which provide potential fuels, coupled with climatic seasonality where droughts convert this productivity into available fuels. California's mediterranean climate provides conditions conducive to extensive wildfires through alternating seasons of good growing conditions with extreme drought. These fire prone landscapes are home to an ever increasing human population, which creates challenges for management of these ecosystems. To understand the historical basis of this problem, and potential solutions, we need to recognize the important regional variation in fuel structure and its role in determining fire regimes. Human impact through fire suppression has been very different in montane forests than in coastal and foothill shrublands. These differences have resulted in profoundly different management dilemmas. The annual autumn Santa Ana winds in Southern California create one of the most severe fire environments in the world, and because of the high population density, it has one of the greatest fire management challenges. Historically management has focused on trying to control fires, but increasingly it is clear that changes in land planning and human infrastructure will be necessary if we are to reduce losses of property and lives. Climate has always played a dominant role in our fire regime and in order to predict future climate change impacts on fires we need to clearly understand the causal relationship between drought and wildfires and our limited capacity for altering fire behavior.

10. EFFECTS OF N DEPOSITION ON RIVERSIDEAN SAGE SCRUB

Edith B. Allen. Department of Botany and Plant Sciences, University of California, Riverside, 92521

Anthropogenic nitrogen deposition has been occurring in western Riverside County for the past half-century, and during the same time period there has been extensive vegetation-type conversion of Riversidean sage scrub to exotic annual grassland. Levels as high as 30 kg N/ha/yr occur as dry deposition from automobile emissions, with highest levels in urban northern regions and decreasing along a gradient southward. To test the impacts of elevated N on vegetation, we observed changes in vegetation along a N deposition gradient and also in N-fertilized plots at a site with relatively low N deposition. Exotic grass cover was positively related to elevated soil N along the gradient, while native shrub and forb cover and richness were negatively related to soil N. Furthermore, arbuscular mycorrhizal fungi decreased in diversity and effectivity as mutualists with increasing soil N along the gradient. Fertilization with 60 kg N/ha/yr caused an increase in biomass in exotic grass after two years, while decreases in native forb cover occurred after 11 years of fertilization. Shrub cover did not change significantly during this time period. Grass biomass of 0.5–1 T/ha in soils with elevated N may be a cause of more frequent fire, as has occurred in the Riverside area. The combination of increased grass fuel for fire, more frequent fires, and decreased effectivity of mycorrhizal fungi for native plant establishment following fire, may drive the conversion of Riversidean sage scrub to annual grassland.

11. COASTAL SAGE WATER RELATIONS AND POTENTIAL INVASIBILITY

A.L. Jacobsen and R.B. Pratt. California State University, Bakersfield, Department of Biology, Bakersfield, CA, 93311

Soil moisture is likely a limiting resource in arid and semi-arid environments for woody shrub species. Seasonal soil moisture was assessed in a coastal sage scrub community and in two adjacent plant communities of similar soil texture. Water potential of all of the dominant woody plant species occurring in these communities were also measured seasonally. The coastal sage community had the moistest dry season soil (20%), compared to a Mojave Desert site (7%) and a chaparral site (10%). These differences in soil moisture are related to differences in precipitation (between the Mojave Desert and other two sites) and to differences in plant water use (between the coastal sage and chaparral which both receive similar precipitation). Previous work finds that 18% soil moisture is an important threshold for woody plant seedling recruitment and the coastal sage community remains above this soil moisture threshold year round. Of the three communities, the coastal sage community may therefore be particularly susceptible to invasion by woody shrub species since its soil moisture content would allow for germination and persistence of a wider range of potential invaders. This may relate to successional dynamics in areas where coastal sage scrub is replaced be chaparral vegetation over time.

12. ECOPHYSIOLOGY OF COASTAL SAGE SCRUB OF SOUTHRN CALIFORNIA

R. Sharifi and P.W. Rundel. Department of Ecology and Evolutionary Biology, Los Angeles, CA 90095

Despite the rapidly diminishing areas of coastal sage scrub habitat in Southern California, and the fragmentation of many existing stands, there are surprisingly few data on the ecology and ecophysiology of individual coastal sage shrub species. Our study site is located in Forrestal Nature Preserve (FNP), City of Rancho Palos Verdes, which is a mixed community of plant species with different adaptive strategies, including shrubs with evergreen, sclerophyllous leaves, as well as drought-deciduous species. The study species include woody evergreens (*Rhus integrifolia*, *Baccharis pilularis*), semi evergreen shrubs (*Artemisia californica*; *Eriogonum cinerium*; *Eriogonum fasciculatum*) and drought deciduous shrubs (*Salvia leucophylla*; *Salvia mellifera*, *Encelia californica*). Seasonal patterns of midday water potential of the drought deciduous-species were highly variable, ranging from −1.5 MP during the rainy season to extremely low water potentials of −8.0 MPa in late summer. There was little fluctuation in the seasonal patterns of water potential in *Malosma laurina*. During the extreme summer drought, the minimum midday water potential reached by *Malosma laurina* was only −1.5 MPa. *Malosma laurina* an evergreen sclerophyllous shrub has a deep root system that taps ground water and thus maintains high water potentials throughout summer drought.

Our studies of comparative photosynthetic capacity have demonstrated that there is a wide range of rates between species. *Salvia leucophylla*, *Salvi mellifera* and *Encelia californica* had high photosynthetic rates (25–28 μmol m^{2} s^{1}, whereas evergreen species such as *Rhus integrifolia* and *Baccharis pilularis* had low rates of only 7–12 μmol m^{-2} s^{-1}. Semi-evergreen species had intermediate rates of photosynthesis.

13E. DEER BROWSE AFFECTS ON POST-FIRE COASTAL SAGE REGENERATION ON SANTA CATALINA ISLAND

A.R. Ramirez[1], R.B. Pratt[1], A.L. Jacobsen[1], and S.D. Davis[2]. [1]California State University, Bakersfield, Department of Biology, Bakersfield, CA 93311; [2]Pepperdine University, Natural Science Division, Malibu, CA 90263

Browsing by alien mule deer may reduce survival of post-fire resprouting dominant shrubs on Santa Catalina Island, and lead to vegetation type conversion from native shrubs to invasive exotic grasses and forbs. Three deer exclosures were established in a recent burn to protect *Hetermeles arbutifolia* (Rosaceae) from browse. Areas adjacent to exclosures were established for comparison. Unburned adults served as a control. We hypothesized that deer browse would negatively impact both resprout success and physiological performance. To test our hypotheses we measured plant mortality, canopy death (%), pre

-dawn water potential (Ψ_{pd}), stem elongation (mm/day), plant canopy area (m^2), maximum net carbon assimilation (A_{nmax}), photosynthetic capacity (F_v/F_m), stomatal conductance (g_s), and lignotuber starch content. Browsed resprouts had greater levels of mortality compared to non-browsed resprouts (mortality = 53% and 12%, respectively; $P = 0.05$). Stem elongation, plant canopy area and A_{nmax} for non-browsed resprouts were significantly greater compared to browsed resprouts ($P < 0.05$), but g_s was not significantly different. Pre-dawn water potentials, during the dry season (August) and in the driest year in recorded history, indicated that browsed and non-browsed plants were well hydrated ($\Psi_{pd} > -0.9$ MPa), whereas unburned plants showed water stress (Ψpd =). Lower values of A_{nmax}, F_v/F_m, and canopy area for browsed resprouts all point to a decreased ability to capture CO_2, which may lead to carbon reserve depletion and ultimately starvation. Alien deer browse apparently diminishes resprout success, which is likely caused by carbon starvation and not water stress

14E. THE ROLE OF RAINFALL PULSES, RESOURCE AVAILABILITY, AND FIRE IN THE CONVERSION OF COASTAL SAGE SCRUB TO ANNUAL GRASSLAND COMMUNITIES

Leah Goldstein, Matt Talluto, Eva Hernandez, and Katharine Suding. Department of Ecology and Evolutionary Biology, University of California, Irvine, CA 92697

Climate change models predict that in mid-latitude regions rainfall event sizes will increase and frequency will decrease. These changes in rainfall distribution may influence the success of invasive species, particularly when invaders and residents differ in their relative responses to soil moisture. The shrub-dominated coastal sage scrub (CSS) communities have declined at a rapid rate and have been converted to exotic annual grass dominated systems. As fire disturbance is increasing in frequency, the interactions between reestablishing CSS and invader species after a fire may be particularly important in this conversion process. We hypothesized that (1)CSS is more vulnerable to invasion after fire, and that (2)competitive hierarchies between invader species and reestablishing CSS would shift in response to changes in rainfall distribution. Predicted changes of larger, less frequent rainfall events should favor species like the CSS shrubs with deeper roots and greater tolerance to dry periods. Through CSS surveys, we found that sites with high fire frequencies had the greatest declines in CSS cover over the past 70 years. We also established exotic grass, CSS seedling, and competition plots in an additive design, and manipulated rainfall event size and frequency. We found that exotic grasses had a strong competitive impact on CSS seedlings in all rainfall treatments, with the strongest effect when rainfall events were more frequent. Results indicated that disturbance reduces CSS's ability to resist invasion, that exotic invaders suppress reestablishment of CSS seedlings, and that predicted changes in rainfall distribution may help to offset the trend in CSS decline.

15. DIVERSITY PATTERNS IN CALIFORNIA SAGE SCRUB

Jon E. Keeley[1,2], C.J. Fotheringham[2], Melanie Baer-Keeley[3], and James B. Grace[4]. [1]USGS, Western Ecological Research Center, Sequoia-Kings Canyon Field Station, Three Rivers, CA 93271; [2]Department of Ecology & Evolutionary Biology, University of California, Los Angeles, CA 90095; [3]Resources Division, Sequoia National Park, Three Rivers, CA 93271; [4]USGS, National Wetlands Research Center, Lafayette, LA, 70506

Plant community diversity, measured as species richness, is typically highest in the early postfire years in California sage scrub. However, this generalization is overly simplistic and the present study demonstrates that diversity is determined by a complex of temporal and spatial effects. Characteristics of the disturbance event, in this case fire severity, can alter postfire diversity, both decreasing and increasing diversity, dependent on life form. Spatial variability in resource availability is an important factor explaining patterns of diversity, and there is a complex interaction between landscape features and life form. Temporal variability in resource availability affects diversity, and the diversity peak in the immediate postfire year (or two) appears to be driven by factors different from subsequent diversity peaks. Early postfire diversity is influenced by life history specialization, illustrated by species that spend the bulk of their life cycle as a dormant seed bank, which is then triggered to germinate by fire. Resource fluctuations, in particular precipitation, may be associated with subsequent postfire diversity peaks. These later peaks in diversity comprise a flora that is compositionally different from the immediate postfire flora, and their presence may be due to mass effects from population expansion of local populations in adjacent burned areas.

16E. CLIMATE ENVELOPE MODELING IN CALIFORNIA SAGE SCRUB: DEFINING THE BIOCLIMATIC NICHE

E.C. Riordan and P.W. Rundel. University of California, Los Angeles, Department of Ecology and Evolutionary Biology, Los Angeles, CA, 90095

Recent advances in species distribution and ecological niche modeling are proving valuable tools for ecosystem conservation and management. We used ecological niche modeling to define the bioclimatic niche, or envelope, of California sage scrub. Using point localities from georeferenced herbarium records, we model the potential distribution and bioclimatic envelopes of 13 characteristic sage scrub species based upon current climate conditions. Within sage scrub, we distinguish between three geographically based floristic elements: southern coastal species (e.g. *Encelia calfornica*, *Salvia apiana*), coastal-interior disjunct species (e.g. *Croton californica*, *Encelia farinosa*) and broadly distributed species (e.g. *Artemisia californica*, *Mimulus aurantiacus*). In addition, we use MAXENT, a recent maximum entropy algorithm, to model species distribution and provide climate-based regional habitat suitability maps for species and floristic groups. With applications in predicting impacts of climate and land cover change and quantifying invasive species' expansion, species distribution and ecological niche modeling hold great potential for the conservation of sage scrub in California.

17. ENVIRONMENTAL DRIVERS OF LANDSCAPE-SCALE COASTAL SAGE SCRUB CONVERSION TO EXOTIC GRASSLAND

K.L. Preston[1], P. Sadler[2], R. Johnson[1], G. Miller[2], and E. Allen[3]. [1]Center for Conservation Biology, University of California Riverside, 1303 Webber Hall, Riverside, CA 92521; [2]Department of Earth Sciences, UC Riverside, Riverside, CA 92521; [3]Department of Botany and Plant Sciences, UC Riverside, 2129 Bachelor Hall, Riverside, CA 92521

Type conversion of coastal sage scrub vegetation to exotic grassland is occurring at a large scale across the southern California landscape. This transformation is attributed to human-caused processes such as altered fire regimes and nitrogen deposition resulting from air pollution. To evaluate the relative importance of natural and anthropogenic environmental factors in this process we developed models predicting conversion of coastal sage scrub to non-native grassland over a 70 year period in western Riverside County. We used a vegetation map created from Wieslander surveys in the early 1930s to compare with vegetation mapped by the California Department of Fish and Game with 2001 aerial photographs to identify locations where coastal sage scrub converted to non-native grassland or remained as coastal sage scrub. We used Geographical Information Systems to assemble various environmental attributes at each sampling location including measures of topography, climate, fire regime, geology and modeled levels of nitrogen deposition. We employed an information theoretic approach to compare models with different combinations of environmental variables and to identify candidate models that best predicted conversion of coastal sage scrub to exotic grassland. We used the candidate models to identify percent slope and nitrogen deposition as important in this landscape-scale conversion process. Locations with shallower slopes and higher total nitrogen deposition were more likely to convert to exotic grassland. While fires were more frequent and larger and geology tended toward sedimentary soils at points that converted to exotic grassland, these variables did not contribute significantly to the candidate models.

18. IMPACTS OF ARGENTINE ANTS ON COMMUNITY PROCESSES IN CALIFORNIA SAGE SCRUB

D.A. Holway. Section of Ecology, Behavior & Evolution, Division of Biological Sciences, University of California at San Diego, MC 0116, 9500 Gilman Drive, La Jolla, CA 92093-0116

In the coastal sage scrub of southern California, dry conditions strongly limit invasion by Argentine ants (*Linepithema humile*). Where soil moisture levels are high enough, however, *L. humile* readily invades scrub habitats and displaces a majority of native ant species. Because of the Argentine ant's intolerance of hot, dry conditions and because of its inherent dispersal limitations, native ant displacement along natural and artificial moisture gradients often resembles an edge effect, the magnitude of which is inversely proportional to the suitability of the physical environment. Control strategies for this invader might thus focus on reducing urban and agricultural run off into natural areas. The homogenization of ant communities that occurs following invasion results in additional ecological effects. Known impacts extend to animals that prey upon ants and to plants that rely on ants for seed dispersal and protection from herbivores.

19. COASTAL SAGE SCRUB RESTORATION AT AN AUDUBON CALIFORNIA SANCTUARY: A RESEARCH-BASED, NON-CHEMICAL APPROACH

S.A. DeSimone. Audubon California's Starr Ranch Sanctuary, 100 Bell Canyon Rd., Trabuco Canyon CA 92679

Restoration of rare coastal sage scrub habitat at Audubon California's Starr Ranch Sanctuary in southern California commences the second year of non-chemical control of the exotic herbaceous perennial, *Cynara cardunculus*, which has invaded 251 ha of native and degraded grassland stands at the 1575 ha preserve. Because analyses of aerial photoseries taken over 48 years revealed gradual coastal sage scrub colonization of grasslands, we decided to actively restore 102 ha of *C. cardunculus*-infested sites in which shrub species have begun colonization. Results from a factorial experiment established an optimum seeding rate and soil tamping technique. Restoration practices were further refined with a second experiment that showed that a combination of direct seeding and plug planting spaced over the growing season would be beneficial in our semiarid region. Non-chemical control of other exotic species in restoration sites is ongoing. Previous research demonstrated a facilitating role of small herbivorous mammals in shrub colonization of grasslands. Current research focuses on the possible role of small mammals in controlling palatable exotic species in restoration sites. Long term data collection on effects of restoration on both small mammals and birds commenced in 2004 and is beginning to indicate positive relationships. Vegetation monitoring of active and passive restoration processes in a total of 26 ha over three years showed 50–60% native shrub cover in treatment areas with baseline 0–5% native cover.

20. COUNTY OF LOS ANGELES COUNTYWIDE STORMWATER/URBAN RUNOFF PUBLIC EDUCATION PROGRAM

Kimberly Y. Lyman. County of Los Angeles Department of Public Works, Alhambra, CA, 91803

The County of Los Angeles (County) developed a comprehensive public education program in compliance with the 2001 National Pollutant Discharge Elimination System Permit to inform and remind residents that their behaviors can contribute to stormwater pollution. The pollution prevention messages are circulated to County residents through a variety of media outlets including: outdoor billboards; bus tails and bus cards; radio, television, and print; movie theaters; Internet marketing; and collateral materials. We convey campaign messages through mass media and targeted businesses such as home improvement and pet stores. The County evaluates its public outreach efforts through an annual resident survey, website hits, and the number of calls received through our toll-free environmental hotline. The 1997–2006 survey results indicate a decline in the occurrence of several polluting behaviors as self-reported by survey participants.

21. PRODUCT SUBSTITUTION: DIAZINON

G.A. Brosseau. California Stormwater Quality Association (CASQA), P.O. Box 2105, Menlo Park, CA 94026

Source controls, one of the two general categories of best management practices (BMPs), work by keeping potential pollutants out of stormwater while the other major category of BMPs – treatment controls work by removing potential pollutants once they are in stormwater. Most source controls are focused on physically keeping potential pollutants out of contact with rainfall and stormwater runoff

through covering, berming, or cleaning. 'True source control', a subset of source controls, focuses on the original source of a potential pollutant by eliminating or significantly reducing the existence of the potential pollutant, thereby negating the need to physically prevent contact with rain or runoff.

The focus of most true source control efforts to-date has been human-made products. Products are a natural for true source control because their source is clear and finite (e.g., a company, a factory). Many times it is not the product per se that is the problem but a particular form of the product or a particular ingredient in the product. This fact lends itself to an approach called product substitution in which substitute products or ingredients are developed and then promoted or required to be used. The pesticide diazinon provides a case study of how true source control can be used to reduce stormwater pollution in a quantitative and measurable way.

22. USING COMMUNITY BASED SOCIAL MARKETING TO INCREASE USED OIL RECYCLING IN LOS ANGELES

Joyce Amaro. City of Los Angeles, Stormwater Public Education Program, 2714 Media Center Drive, Los Angeles, CA 90065

The City of Los Angeles Stormwater Public Education Program is currently using methods of Community Based Social Marketing (CBSM) to drive the direction of its used oil recycling public education program. The program has recently revamped the "look" of the public outreach design to follow CBSM tenets of modeling and norm appeals. In addition to aesthetic design elements, Los Angeles is also employing programmatic uses of CBSM. The program is currently conducting baseline surveys in the Harbor Gateway area as part of an abandoned oil pilot program. The surveys will assess the barriers and motivators of Do-it-Yourself oil changers in order to tailor an outreach campaign that aims to curb incidences of abandoned oil. Pilot programs will be conducted throughout the City and then evaluated to measure successes and areas for improvement. The ultimate goal will be to refine the pilots in order to transition into City-wide roll out of the program.

23. ENFORCEMENT OF WATER WASTING-URBAN RUNOFF CODES & BMPS

N. Shapiro. City of Santa Monica, Environmental Programs Division, 200 Santa Monica Pier, Suite K, Santa Monica, CA 90401

The City of Santa Monica Watershed Management Program contains two strategies to reduce pollution found in urban runoff. The first strategy is post-construction BMPs in building projects to control polluted runoff, whether it is runoff leaving one's site or after it has left a site. The second strategy, and focus of this presentation, is preventing pollution from contacting runoff and reducing the production of runoff during dry weather, keeping it out of the municipal storm drain system. This strategy is a source control program. The City employs various patrols and inspections to seek out violators of the City's two main ordinances for watershed management, the Wasting Water and Urban Runoff Pollution Mitigation ordinances. Through these two municipal codes, City staff has authority to issue fines ranging from $250–500 for violations. However, the first strategy when enforcing these codes is to educate the public about the problems and the solutions, to work with the public to correct problems. This type of strategy offers a long-term win-win solution and recruits more of the public to participate actively in helping the City implement its Watershed Management Program.

24. CALTRANS' USE OF AND RESEARCH ON VEGETATED BIOFILTER BMPS

K.L. Dreher[a] and M.M. Kerner[b]. [a]California Department of Transportation, Division of Environmental Analysis, Sacramento, CA, 94274; [b]California State University – Sacramento, Office of Water Programs, Sacramento, CA, 95819-6025

Caltrans has a research team dedicated to developing and improving structural and non-structural Best Management Practices (BMPs) for reducing the impact of highway runoff on receiving waters. A particularly effective and feasible category of structural BMPs that Caltrans has been implementing and researching are vegetated biofilters. Biofilters are treatment devices that incorporate vegetation to promote the reduction of pollutants such as litter, soil particles, and metal particulates in stormwater discharge. Treatment mechanisms include filtration through vegetation, sedimentation, adsorption to soil particles, microbial processes, and infiltration. Caltrans' commonly utilizes biofiltration BMPs such as biostrips, bioswales, and wet basins to improve highway runoff quality, as their BMP Retrofit Pilot Study has shown these BMPs to be effective in cost and performance for reducing solid particles and heavy metals from highway runoff. Caltrans' Roadside Vegetated Treatment Sites (RVTS) Study assesses ways to improve implementation and effectiveness of biostrips and bioswales by evaluating how site characteristics such as roadside vegetation, slope inclinations, and soils influence treatment. Additional research is attempting to expand the Caltrans' toolbox of effective and efficient use of vegetated BMPs.

25. PERFORMANCE OF THE BALLONA FRESHWATER MARSH AS A MULTI-PURPOSE CONSTRUCTED WETLAND

Edith Read. E Read and Associates, Inc., Orange, CA, 92866

The Ballona Freshwater Marsh consists of 24 acres near Playa del Rey and Culver City, California. The Marsh is part of a 51-acre freshwater wetland under construction by Playa Vista as mitigation for development impacts. The watershed area is about 1,100 acres, of which about half consists of the Playa Vista development with water quality Best Management Practices (BMPs), and half consists of older neighborhoods without water quality BMPs. The wetland system was designed for habitat, runoff treatment, and flood management. Although the wetland as a whole is not yet complete, five years of monitoring indicate a mix of positive performance trends and challenges for maximizing habitat and water quality. Goals for bird use, vegetation structure, and species richness have been met. Comparison of water quality data to values predicted when the Marsh was designed in the 1990s show greater inputs of total suspended solids, total phosphorus, and total nitrogen than predicted, but lower concentrations of metals. Removal efficiencies depend on constituent, input concentration, and season, but at their highest levels approach 90 percent for metals such as copper and zinc that are plant nutrients. Metal and trash inputs from the portion of the watershed without water quality BMPs have been consistently higher compared to the portion of the watershed with BMPs. Management of emergent vegetation, populations of a non-native fish species, and application of a pesticide required by the local vector control agency for mosquito abatement may depress habitat values and water quality below maximum potential.

26. ENFORCEMENT OF WATER WASTING-URBAN RUNOFF CODES & BMPS MEETING THE TRASH TMDL IN THE CITY OF LOS ANGELES

Morad Sedrak. City of Los Angeles, Bureau of Sanitation, Watershed Protection Division, Los Angeles, CA, 90015

The City of Los Angeles is mandated by the Trash TMDL to reduce its trash contribution to the LA River and Ballona Creek by 10% each year for a period of ten years. The City's strategy for compliance utilizes a two-pronged approach, i.e., implementing institutional measures and installing structural trash control devices. Prior to carrying out this approach, the City completed several studies to guide its efforts for developing a cost effective implementation plan. An initial study identified three trash generation areas in the City (low, medium, high), which revealed that the high areas contributed 60% of the City's trash. Two additional studies on CB inserts and opening screen covers used by the City, concluded that their effectiveness are 100% and 86%, respectively. In July 2007, the City's catch basin inserts were certified as full capture devices by the LARWQCB. Having implemented various structural measures over the course of the past four years, the City concluded that implementation of a combination of CB inserts and opening screen covers in the high trash areas and opening screen covers at all remaining catch basins is the most feasible, practical and cost effective approach for compliance. Thus far, the City has installed 7,400 inserts and 14,300 opening screen covers.

27. SALT CREEK OZONE TREATMENT FACILITY FOR URBAN RUNOFF, DANA POINT, CALIFORNIA

Brad Fowler. P.E., Director of Public Works & Engineering Services, City of Dana Point, 33282 Golden Lantern, Dana Point, CA 92629

The City of Dana Point was determined to find an effective solution to beach impairments resulting from urban runoff at two highly-used beaches, Monarch Beach and Salt Creek County Beach *in the near term*. Even with the aggressive source control strategies that have been implemented within the urbanized watershed, including inlet filters, streetsweeping, stream restorations, over-irrigation outreach, and commercial inspections; no notable improvements were observed downstream at the beaches and ocean. The frequent beach postings and resulting potential health concerns and negative economic impacts required immediate action. The solution: the Salt Creek Ozone Treatment Facility at the bottom of Salt Creek which removes bacteria, potential viruses and a number of other pollutants commonly found in urban runoff. The state of the art facility diverts and treats 500–1,000 gpm of dry weather urban runoff. As the facility is entering its third season of operation, this presentation will cover:

- Project Effectiveness & Challenges
- To Permit or Not? The fate of the "Facility that Extracts Treats & Discharges (FETD)" - Regulatory agencies struggle as to whether treatment BMPs require discharge permits
- Taking the Next Step - Reuse Obstacles: Permitting, Funding, Brine Disposal & Water Rights
- Battling Bacteria TMDLs: "End of pipe" treatment does have its place.

28. REUSING ONE'S LOCAL WATER RESOURCES – DRY WEATHER RUNOFF REUSE THE SMURRF WAY

N. Shapiro. City of Santa Monica, Environmental Programs Division, 200 Santa Monica Pier, Suite K, Santa Monica, CA 90401

The City of Santa Monica Watershed Management Program includes a strategy to harvest and reuse both wet and dry weather runoff. Both are responsible for pollution of the Santa Monica Bay and exceedances of state health bacterial limits for water quality. As regulations have become stricter to clean up pollution found in runoff, the City decided to embark on a more sustainable watershed strategy as it planned on how to meet various runoff requirements – runoff reuse. With ongoing water supply challenges as demand rises and reliable supplies decrease, the City believes that the most sustainable strategy is to use as much of one's local water supplies as possible and reduce dependence upon imported water supplies. Instead of treating runoff pollution and then discharging the treated runoff to the Santa Monica Bay, wasting a water resource, the City decided to adopt a sustainable strategy of water reuse. The Santa Monica Urban Runoff Recycling Facility (SMURRF) treats up to 500,000 gallons per day of dry weather runoff for reuse in landscape irrigation and indoor use. This strategy reduces the City's dependence on imported potable water by 2–4%. The facility treats over 90% of the City's dry weather runoff from its two main storm drains at Pico Boulevard and the Santa Monica Pier. Besides treating urban runoff, the SMURRF offers visitors a place to come and learn what urban runoff is and what solutions are available to reduce this pollution source.

29F. LIFE HISTORY OF SARGO, *ANISOTREMUS DAVIDSONII*, IN THE SOUTHERN CALIFORNIA BIGHT

M.C. Mandrup and D.J. Pondella, II. Vantuna Research Group and Department of Biology, Moore Laboratory of Zoology, Occidental College, Los Angeles, CA 90041

Sargo, *Anisotremus davidsonii*, is a common member of the rocky reef fish assemblage in the Southern California Bight, however little is known about the life history of this Haemulid. Age and growth analyses were preformed on 686 individuals using otoliths. The maximum age was 23 years and the von Bertalanffy growth parameters for all individuals were $L_\infty = 278.47$ mm, $k = 0.224\ \mathrm{yr}^{-1}$, and $t_0 = -1.228$ yr. Growth estimates for both sexes indicated that females grew significantly larger and faster than males. Gonosomatic indices (GSI) peaked during the summer indicating that this is their spawning season with maximum GSI for males = 6.08% and females = 4.25%. Both sexes were found in all age classes with an overall male to female ratio of 56:44 that was significantly different from a 50:50 ratio ($\chi^2 = 7.0$; $p < 0.01$). GSI values and sex ratio were consistent with group spawning and sperm competition. Mean catch-per-unit-effort from 1996–2004 fluctuated temporally and spatially at 10 sites, and was significantly

correlated with sea surface temperatures (r = 0.616; p = 0.006). Catch declined from 2000–2004. Estimates for annual mortality (A = 0.1950) and the instantaneous coefficient of total mortality (Z = 1.6346) were calculated from samples collected from 2002–2004.

30M. MICROSATELLITE DNA ASSESSMENT OF MULTIPLE PATERNITY IN THE VIVPAROUS ROCKFISH *SEBASTES MELANOPS*

K.W. Karageorge and R. Wilson, Jr. Department of Biological Sciences, California State University, Long Beach, Long Beach, CA 90840

Microsatellite DNA loci were employed in a natural population of the viviparous black rockfish, *Sebastes melanops*, to 1) quantify the incidence of multiple paternity in a sample of brooded females, 2) estimate relative paternal contributions of multiply sired broods, where evident, and 3) to characterize the genetic mating system of *S. melanops*. Brooded females (n=15) and samples of their progeny were assayed to determine their multi-locus genotypes, and progeny array data was then analyzed with parentage software to determine the number of (reconstructed) sires contributing to each female's brood. The total expected probability of excluding a random male in the population as being the sire of a brood was p=0.97. Parentage analysis revealed that 66% (10/15) of the broods were multiply sired (frequency of multiple paternity), and the mean number of sires per brood was 2.9 (sd=0.83), ranging from 1 to 4 sires. The relative paternal contribution was skewed in most multiply sired broods, with one male inseminating a majority of the progeny, suggesting the possibility of sperm competition in a species that exhibits prolonged sperm storage. The results provide strong genetic evidence of a promiscuous mating pattern among some female *S. melanops*, i.e., polyandry, resulting in full and half-sib relationships among brooded progeny and a polygamous genetic mating system for this economically-important nearshore rocky reef species.

31. LONG-TERM POPULATION TRENDS OF SOUTHERN CALIFORNIA SCIAENIDS IN THE PRESENCE OF OCEANOGRAPHIC CHANGE AND POWER PLANT ONCE THROUGH COOLING

Eric F. Miller[1], Daniel J. Pondella, II[2], and Kevin T. Herbinson[3]. [1]MBC Applied Environmental Sciences, Costa Mesa, CA; [2]Vantuna Research Group, Occidental College, Los Angeles, CA; [3]ACT Environmental, Inc., Laguna Hills, CA

Sciaends comprise a substantial portion of the southern California coastal ichthyofauna. Despite their contribution to the overall abundance, little information is known about their long-term population trends, except for the heavily fished white seabass (*Atractoscion nobilis*). For the non-commercial species, such as *Seriphus politus*, *Genyonemus lineatus*, *Roncador stearnsii*, *Menticirrhus undulatus*, *Cheilotrema saturnum*, and *Umbrina roncador* limited temporal analysis of their standing stock has been attempted, and this is limited to only *U. roncador* and *C. saturnum*. Increasing attention to coastal fish population levels, in light of the general decline of most coastal fishes, has spurred interest into the causes of these declines. To this end, fishery independent datasets (impingement, otter trawl, scientific gillnet, and nearshore ichthyoplankton) were analyzed to evaluate these trends. From these, observed abundances were compared to oceanographic data (sea surface temperature, multivariate ENSO index, Pacific Decadal Oscillation index, etc.), annual maximum kelp canopy for the San Diego/Orange Counties coastline and Palos Verdes Peninsula, as well as cooling water flow rates at local power plants. Recruitment indices, such as annual abundance of young of the year and estimated hindcasted mortality adjusted recruitment (*S. politus*, *G. lineatus*, and *U. roncador*), were examined against the same parameters as were observed abundances.

32E. INVESTIGATING ELK KELP'S (*PELAGOPHYCUS PORRA*), INABILITY TO INVADE POINT LOMA GIANT KELP BEDS

Stacie M. Fejtek[1], Matthew S. Edwards[1], and Kwan-Young Kim[2]. [1]Department of Biology, San Diego State University, San Diego, California, USA; [2]Department of Oceanography, Chonnam National University, Gwangju, Korea

The Elk Kelp, *Pelagophycus porra*, is commonly observed in deep (20–30 m) water on the outer edge of Giant Kelp, *Macrocystis pyrifera*, forests in southern California and northern Baja California, Mexico, but rarely occurs in shallower water within the giant kelp beds. *Pelagophycus* exhibits a heteromorphic life history, alternating between a macroscopic sporophyte and a microscopic gametophyte. Therefore, consideration of both life history stages allowed us to study the apparent inability of *Pelagophycus* to encroach into the more abundant Giant Kelp beds along the southern California coast. Transplanting juveniles inshore revealed that the onset of reproductive maturity occurred sooner at shallower depths with no depression in growth. Experimental removal of *Macrocystis* and the addition of *Pelagophycus* reproductive spores using sori-filled mesh bags resulted in no recruitment of *Pelagophycus* within the Giant Kelp beds. A methodological control within the *Pelagophycus* beds showed a significant difference in *Pelagophycus* recruitment within 1–2 m from sori bags as compared to natural recruitment within the site. Culture experiments were carried out in the laboratory to investigate the effects of increasing light levels on the microscopic life history stages of *Pelagophycus*. Both embryonic sporophyte and gametophyte densities dropped to zero when moved to higher levels equivalent to those found within the *Macrocystis* beds. Sensitivity of *Pelagophycus* microscopic stages was also observed when grown constantly at higher light levels. This light sensitivity of the microscopic stages is likely the major factor inhibiting *Pelagophycus* from permanently establishing within the *Macrocystis* beds.

33. AN EMERGY INPUT ANALYSIS OF SANTA MONICA BAYKEEPER'S KELP RESTORATION PROJECT

Brian Meux. Santa Monica Baykeeper, Marina del Rey, CA 90292

Santa Monica Baykeeper's Kelp Project was an answer to the large-scale degradation of giant kelp (*Macrocystis pyrifera*) forests of Santa Monica Bay, California. From 2003 to 2006, this large-scale experiment transformed a sea urchin barren into a productive and resilient kelp forest ecosystem off Escondido Beach, Malibu. Restoration success was measured by *Macrocystis* density values reaching 0.1 plants/m^2 and t-Test statistical analysis. Marine restoration can be expensive and difficult, and as of yet no study has linked energy inputs with the success of a kelp restoration project. This study used H.T. Odum's Emergy methodology to estimate the quantity of human and environmental Emergy inputs for direct comparison to each other and the restoration success. The human input's Empower density was found to be 4.67×10^{17} sej/ha/yr, compared to the environmental input's Empower density of 3.00×10^{18} sej/ha/yr. The Emergy Investment Ratio for the Kelp Project was 0.16 during the study period, with human inputs decreasing during the study period. Urchin relocation composed 83% of all restoration diving activities, restoring the process of urchin predation. This analysis provides insight into improving the Emergy efficiency of the kelp restoration process, including site selection, monitoring, restoration activities and design. Scientists and practitioners may integrate this method with current tools that guide ecological restoration and the assessment of kelp restoration projects.

34. SOCIAL-ECOLOGICAL INTERACTIONS IN GIANT KELP FORESTS

D.C. Reed. Marine Science Institute, University of California, Santa Barbara, CA. 93106

Most natural systems are influenced to some degree by humans, yet there has been a tendency to target relatively pristine sites when studying many ecological patterns and processes. There is growing realization that true progress in understanding the impacts of environmental change can only come about by studies that account for interactions and feedbacks between humans and the environment. Here I present a conceptual framework adopted by the US Long Term Ecological Research Network for studying social-ecological interactions, and I apply this framework to giant kelp forests in southern California. Within the context of this framework, kelp forests and humans are linked by the ecosystem services that kelp forests provide to society, and by the impairments to kelp forest structure and function that are caused either directly or indirectly by human activities. Data collected by the Santa Barbara Coastal Long Term Ecological Research project are used to illustrate direct and indirect effects among humans, environmental drivers, and kelp forest structure, function and services. Patterns observed to date indicate the need for long term data in evaluating the strength of the interactions among these factors and their underlying causes.

35. PATTERNS OF FISH AND INVERTEBRATE ASSEMBLAGES AMONG KELP FORESTS IN SAN DIEGO

P.E. Parnell. Integrative Oceanography Division, Scripps Institution of Oceanography, La Jolla, CA, 92093-0227

Patterns of fish and invertebrate occupancy of distinct habitats within several kelp forests off San Diego are remarkably different for many species. Why is this so? Possible reasons include, but are not limited to, (1) nonlinearities in the interaction of habitat type, quantity, and patch sizes, (2) ocean climate, and (3) fishing pressure.

36F. MIDWATER FISH ASSEMBLAGES ASSOCIATED WITH PETROLEUM PLATFORMS ON THE SAN PEDRO SHELF: A COMPARISON WITH ADJACENT NATURAL REEFS

C.J.B. Martin and C.G. Lowe. Department of Biological Sciences, California State University, Long Beach, CA, 90840

Recent ecological studies of petroleum platforms in the Santa Barbara Channel have indicating increased fish community parameters compared to natural adjacent reefs. These data, attributed to platforms acting as *de facto* marine reserves, have led to increased support for platform protection as "Essential Fish Habitat." However, fish communities associated with the more southern platforms on the San Pedro Shelf have remained largely unstudied. Bimonthly SCUBA-based fish surveys were conducted in the midwater regions (to a maximum depth of 31 meters) at six of the seven platforms on the San Pedro Shelf for the period of one year. Diver surveys observed 48 different species associated with platform assemblages on the San Pedro Shelf. A strong distinction was observed between the platforms close to shore (shallower than 18 meters) and those further from shore (deeper than 50 meters). Despite having several common species, the inshore platforms had greater richness while the offshore platforms had greater total density. Seasonal influences were prominent at the offshore platforms with dramatic changes attributed to pelagic baitfish species and *Chromis punctipinnis* (blacksmith) recruitment. Species assemblages were also observed to differ with depth at the offshore platforms. Comparisons are made with data from adjacent natural reefs on the San Pedro Shelf, indicating differences in species assemblages and community structure. Based on these comparisons, habitat quality of San Pedro Shelf platforms are discussed.

37. THE NEARSHORE ROCKY-REEF FISHES OF THE SOUTHERN CALIFORNIA ISLANDS

D.P. Pondella, II. Department of Biology and Vantuna Research Group, Moore Laboratory of Zoology, Occidental College, 1600 Campus Rd. Los Angeles, CA 90041

Underwater surveys of nearshore rocky reef communities were conducted at 88 sites in central and southern California during summer and fall 2004 using a standardized methodology. The project, referred to as CRANE (Cooperative Research and Assessment of Nearshore Ecosystems), was a collaborative effort among scientists at six institutions. Over 225,000 fishes representing 83 distinct species from 40 families were observed at all sites combined. Rockfishes included the most species (14) of all families, followed by surfperches with ten species and sculpins with six species. A multivariate analysis identified groups of geographically-related sites that had a high degree of within-group similarity in their fish assemblages. A northern group of sites from Monterey Bay to Big Sur was characterized by blue rockfish, copper rockfish, cabezon, and striped surfperch. Sites south of Big Sur to Point Purisima formed a central mainland group, while a third group of sites at San Miguel Island and Santa Rosa Island included elements of the northern fauna in addition to greater numbers of black surfperch and kelp bass, among others. Santa Cruz Island and San Nicolas Island had a transitional fish assemblage between the northern groups and a large southern group that included sites at Anacapa Island, Santa Barbara Island, Santa Catalina Island, San Clemente Island, and the mainland from Santa Monica Bay to San Diego. Garibaldi, blacksmith, kelp bass, opaleye and sheephead characterized these southern sites.

38. OVERVIEW OF EFFORTS TO REDUCE FISHERY BYCATCH

Mark Helvey. National Marine Fisheries Service

Fishery bycatch, or fish harvested in a fishery that are neither sold nor kept for personal use, is one of the most significant issues affecting fisheries management. Bycatch, and especially the mortality of such bycatch, can have significant consequences for populations, food webs, and ecosystems. The view that bycatch should be reduced is reflected in national priorities reflecting the global view that discarded portions of fishery catches represent an unacceptable waste of natural resources. Efforts to minimize bycatch and, to the extent bycatch cannot be avoided, minimize the mortality of such bycatch, have become increasingly important priorities for fishery management over the past several years and remains a central challenge. Three primary strategies to minimize bycatch are avoidance, deterrence, and selectivity. This overview discusses these approaches and provides the context for the presentations in this symposium.

39. THE INTERNATIONAL SMART GEAR COMPETITION: INSPIRING INNOVATION BY CAPITALIZING CREATIVITY

M. Osmond. World Wildlife Fund, Palo Alto, CA 94301

WWF's International Smart Gear Competition awards cash prizes for innovative ideas to make fishing more selective. The competition is intended to inspire, reward and promote practical fishing gear designs to reduce fisheries bycatch and to encourage creative thinkers everywhere to share their ideas. The competition is open to eligible entrants from all backgrounds, and the three competitions previously held have attracted entries from around the world. Entrants have included fishermen, students, gear technologists, engineers, chemists, and inventors. An international panel made up of gear technologists, fisheries experts, seafood industry representatives, fishermen, scientists, researchers and conservationists judge the entries and select the winners. WWF then works with industry and partners to advance the winning ideas towards adoption in relevant fisheries sectors.

40. BOTTOM TRAWL PERFORMANCE IN THE CALIFORNIA HALIBUT TRAWL GROUNDS

S.P. Wertz, A.J. Frimodig, M.C. Horeczko, T.J. Mason, B.C. Owens, and M.W. Prall. State Fisheries Evaluation Project, Marine Region, California Department of Fish and Game, Los Alamitos, CA, 90720

Bottom trawling is prohibited in state waters except within the California Halibut Trawl Grounds (CHTG) located off Ventura and Santa Barbara Counties. The trawl fishery operating within the CHTG is primarily a low-volume, high-priced halibut fishery that supplies local specialty restaurants with a live product that commands a price 1.5 times greater than dead product. Commencing April 1, 2008, about 42% of the CHTG will be closed to bottom trawling unless the California Fish and Game Commission (Commission) finds the fishery minimizes bycatch, is not likely damaging seafloor habitat, is not adversely affecting ecosystem health, and is not impeding reasonable restoration of kelp, and other biogenic habitats. To provide the Commission with the best available information, the Department of Fish and Game worked collaboratively with the Southern California Trawlers Association and California Sea Grant to investigate small scale trawl gear interaction with the seafloor in situ with an underwater video camera, and conduct a bycatch study within the CHTG. Data were also analyzed from trawl logs, seafloor mapping, ROV transects, and aerial kelp canopy surveys to document the location of trawl effort intensity relative to the occurrence of kelp and other biogenic habitats. Our results showed that trawl effort occurs primarily over soft bottom with gear having minimal bottom contact. The bycatch rate per pound of retained California halibut for the CHTG was 87% lower than bycatch in the federal limited-entry trawl fishery targeting California halibut. Effects of bottom trawling on ecosystem health were beyond the scope of this study.

41. DEVELOPMENTS IN SCIENTIFIC RESEARCH ON THE USE OF MODIFIED FISHING GEAR TO REDUCE LONGLINE BYCATCH OF SEA TURTLES

Y. Swimmer and C. Boggs. NOAA Fisheries, Pacific Islands Fisheries Science Center, Honolulu, Hawaii 96822

To comply with increased concern for the welfare of our oceans, improved gear selectivity must be a priority for fisheries scientists, managers and industry alike. This talk will summarize research comparing modified fishing gear to traditional methods in pelagic longline fisheries. The ultimate goal of the work is to identify method(s) of longline fishing that effectively reduces the incidental capture of sea turtles while simultaneously maintaining the economic viability of the fishery. Summary of findings to date: 1) Replacement of J and tuna hooks with circle hooks can effectively reduce the deep ingestion of hooks by sea turtle species that tend to bite baited hooks; 2) In fisheries with bycatch of relatively large loggerhead turtles (*Caretta caretta*) or leatherback turtles (*Dermochelys. coriacea*), using large sizes of circle hooks (e.g. 18/0) can substantially reduce the bycatch of both species; 3) In fisheries with bycatch of smaller turtles, using smaller size circle hooks (e.g.16/0) can reduce capture rates of sea turtles when the circle hooks replace other hook styles with smaller widths; 4) Using fish for bait instead if squid can reduce bycatch of sea turtles in fisheries and can also offset the potential loss of swordfish from use of circle hooks. This is not a comprehensive list of effective mitigation methods, and we encourage identification of more bycatch reduction methods to be used alone or in combination with other methods to further improve fisheries selectivity in longline and other coastal or pelagic fisheries.

42. AN OVERVIEW OF FISHING GEAR AND FISHING PRACTICE MODIFICATIONS THAT HAVE RESULTED IN BYCATCH REDUCTION IN CALIFORNIA'S COMMERCIAL AND RECREATIONAL FISHERIES

Angela Louie. California Department of Fish and Game, Los Alamitos, California

Commercial and recreational fishing gear and fishing techniques have evolved over time for many reasons. Some of these changes were due to regulations designed to reduce total catch, which indirectly reduces bycatch. Other changes were intended specifically to reduce bycatch, either of prohibited species, undesirable species, or of individuals below a desired or minimum legal size. This overview will focus on non-trawl fishery gear, in particular hook-and-line, trap (both of which are used in commercial and recreational fisheries), gill net, and round haul net (both of which are used only in commercial fisheries).

43. THE ROLE OF ALLOWABLE FISHING EFFORT IN PROVIDING INCENTIVES TO INNOVATE CONSERVATION TECHNOLOGY

S.M. Stohs. NOAA Fisheries, Southwest Fisheries Science Center, La Jolla, CA 92037-1508

A key commercial fisheries management concern is upholding requirements of U.S. federal conservation laws. Such laws include the Endangered Species Act (ESA), which regulates allowable takes of threatened and endangered species, the Marine Mammal Protection Act (MMPA), which regulates interactions between commercial fisheries and marine mammals, and the Magnuson-Stevens Act (MSA), which requires sustainable management of fisheries. This paper considers the role of allowable commercial fishing effort in providing incentives for developing cleaner gear and fishing techniques coupled with more effective conservation management practices. Overly restrictive limits on allowable commercial fishing effort may prevent fishermen from achieving an economically viable level of fishing effort. In the case of highly migratory target species such as swordfish (*Xiphias gladius*) and highly migratory protected species such as leatherback turtles (*Dermochelys coriacea*), curtailment of U.S. commercial fishing effort may inadvertently outsource fisheries conservation problems to foreign fleets. Policies which promote experimentation with conservation technology subject to compliance with federal conservation mandates can potentially lead to the development of gear and fishing practices which better achieve conservation goals without eliminating the economic viability of affected fisheries. The objective is to achieve a Pareto improvement in conservation technology, providing for either an increase in economic viability at the existing level of conservation, or stricter conservation given the current level of economic viability. Such Pareto improvements can potentially offer mutual benefits to the U.S. commercial fishing industry and to the protected species which are subject to bycatch concerns.

44. CONSERVATION FISHING AGREEMENT – THE FIRST CONSERVATION EASEMENT IN THE OCEAN?

Michael Bell. The Nature Conservancy, 75 Higuera Street, Suite 200, San Luis Obispo, CA 93401. Co Presenter: Edwin "Fast Eddie" Ewing. Commercial Fisherman, Morro Bay, CA

TNC acquired 7 federal trawl fishing permits and 4 trawl fishing vessels, as part of its conservation project that facilitated the closure and protection of 3.8 million acres of seafloor habitat from the trawl impact. One of the vessels and a permit is being used in the Conservation Fishing Agreement, a collaborative effort to explore more sustainable ways to selectively harvest flatfish species. This unprecedented lease agreement is modeled after a conservation easement on land. The agreement carries specific geographic restrictions, monitoring protocols, and terms to allow for the adaptive design of gear over time.

45. METHODOLOGIES FOR SOCIAL AND GEOGRAPHIC INTEGRATION OF MANDATORY AND VOLUNTARY BYCATCH REDUCTION TECHNOLOGY

Ana Pitchon. CSU Dominguez Hills, Department of Anthropology, Carson, CA 90747 and Karma Norman. Northwest Fisheries Science Center, Seattle, WA 98112

Within commercial fisheries, social variables are an often overlooked piece of the conservation puzzle. This is certainly true of technological fixes meant to address issues of bycatch of non-target species in fishing. Since new mitigation technologies are often specific to particular "gear communities," the breadth of their use may be limited. For example, one complication is that fishermen often express identification with both the type of fishery in which they're engaged (e.g. charter recreational or commercial) and the type of gear employed (e.g. trawler or long liner) and these identities can sometimes be located geographically. The NWFSC is currently developing an approach to commercial fisheries data which will address the social and geographic aspects of gear usage. While this methodology is designed to track regulatory impacts, including the imposition of tradable quota systems, such a methodology would aid in finding where technological fixes would be most readily adopted and integrated.

46E. LIFESTYLE AND QUALITY OF HEALTH FOR 19TH CENTURY POPULATIONS IN NORTH AMERICA

S. Fitz-González. California State University, Los Angeles, Department of Anthropology, Los Angeles, CA, 90032

Detailed analysis of skeletal remains may present direct evidence of the biology of past populations, providing insight into health, diet, lifestyle, and violence. Skeletal attributes that may determine the health status or quality of life of a given population are stature, dentition, bone lesions, degenerative joint disease, and trauma. This research paper attempts to glean information about the lifestyle and quality of health for nineteenth century populations in North America by analyzing and comparing published skeletal case studies. After reviewing 13 skeletal samples, patterns of health and lifestyle in the nineteenth century emerge with respect to ancestry, socioeconomic status, geographic location, and age. African-American populations, urban populations, and children reveal the most severe lifestyle and lowest quality of health. The results shed light on nineteenth century issues, such as different access to nutrition, exposure to diseases, and interpersonal violence.

47. TIDAL LOADING RATES FOR FECAL INDICATOR BACTERIA (FIB) IN THE BALLONA WETLANDS, CALIFORNIA: RESULTS OF 12- AND 24-HR SURVEYS

J.H. Dorsey, **P.M. Carter**. Loyola Marymount University, Department of Natural Science, Los Angeles, CA 90045. Sean Bergquist, Santa Monica Bay Restoration Commission, One LMU Dr., Pereira Annex MS 8160, Los Angeles, CA 90045

Densities of fecal indicator bacteria (FIB: total coliforms, *E. coli*, enterococci) were measured in the main tidal channel of the Ballona Wetlands (Los Angeles County) to determine fluxes over varying tidal cycles to address whether or not the wetlands act as a sink or source of these bacteria. Densities of FIB and environmental parameters were measured at a single site every 1.5-hrs over one 12-hr period (2 Mar 2007) and two 24-hr periods (12–13 Jul 2007, 2–3 Aug 2007). Parameters included current flows, replicate surface water samples (n=3) for FIB and turbidity (NTU), and measurements of depth (ft), oxygen (mg/L), temperature (C°), salinity (ppt), and pH collected every 15-min using YSI 6600 continuous recording sonde. Tidal flows (CFS) were greatest during mid flood and ebb tide periods; maximum flows after spring highs ranged from 29.0–43.9 CFS. Turbidity spikes occurred at maximum flood and ebb flows with mean peak NTU values of 14.2 (March), 6.4 (July), and 8.3 (August). FIB loading rates (MPN/m^3/s) were greatest on incoming flood tides during night, then fell throughout daylight hours; total coliform loading rates fell from levels of 10^6–10^8 by two to three orders of magnitude, while E. coli and enterococci fell from levels of 10^5–10^7 by two to four orders of magnitude. Correlation analyses suggest that increased light intensity may be causing diminished FIB densities throughout the day light hours, while FIB density spikes of up to four orders of magnitude appeared to be associated with increased turbidities from sediments resuspended during faster mid- to low ebb flows.

48E. FORAGING ECOLOGY OF THE ELEGANT TERN IN RESPONSE TO NEW MARINE HABITAT AT THE RESTORED BOLSA CHICA ECOLOGICAL RESERVE

J.N. Hendricks and M.H. Horn. Department of Biological Sciences, California State University Fullerton, CA, 92831

The 2006 restoration of the Bolsa Chica Ecological Reserve (BCER) in Orange County, California, provides 235-ha of new marine habitat in the reserve. This expansive marine area more than doubles the total aquatic habitat of the reserve and is located immediately adjacent to nesting sites of the Elegant Tern (*Thalasseus elegans*), a California state Species of Special Concern. This tern is primarily an ocean forager, and we predicted that the species will continue to feed in the ocean despite the accessibility of the new marine habitat. Foraging habitat locations were observed during the 2007 nesting season, and will be recorded throughout the 2008 season. Of the 6,321 Elegant Terns observed returning to the nesting site with a bill load, only 174 (<3%) were associated with foraging in the new marine area. To assess the diet of this species, we identified dropped fish from the nesting areas, bill loads of adult terns returning to feed their young by direct observation, and a few regurgitations. From dietary assessment, most fish species identified can be associated as marine or as marine migrants to estuarine systems, coinciding with our foraging observations. Compared to previous years at BCER, an increase in the number of pipefish was found among the dropped fish samples, comprising ~56% of all dropped fish collected in 2007. These findings indicate that the Elegant Tern continues to be an ocean forager following the restoration, and they suggest a recent increase in pipefish recruitment in southern California.

49E. DEVELOPING *SALICORNIA VIRGINICA* AS A BIO-MONITOR FOR THE HEAVY METALS ZINC AND CADMIUM IN THE BALLONA WETLANDS

James R. Holmquist, Philippa M. Drennan, and James Landry. Loyola Marymount University, Departments of Biology and Natural Science, Los Angeles, CA 90045

The coastal Ballona Wetlands are a part of the highly urbanized Los Angeles watershed. Studies performed on the water quality of the channel feeding the wetlands have shown high levels of heavy metals. It is hypothesized that in a contaminated wetland the widely distributed halophyte *S. virginica* will take up heavy metals along with the salts and thus may be used as a bio-monitor for heavy metal pollution. Five replicates of stem tips and the soil immediately below each plant were collected from 16 sites throughout the Ballona Wetlands. Stem tips were also collected from plants of Huntington Beach Back Bay for comparison. The methods used included: oven drying to establish wet and dry weights for water content, flame photometry to determine sodium and potassium levels, and atomic absorption spectroscopy for zinc (flame analysis) and cadmium (graphite furnace) levels. The concentration of each metal in the plants was correlated with the concentration of metal in the soil by regression analysis. Correlations were positive and significant for both cadmium and zinc. With *S. virginica* established as a reliable bio-monitor, areas of constant elevated cadmium and zinc pollution were identified. Comparison of heavy metal levels in *S. virginica* from Ballona to those of other areas suggests that pollution may be higher in Ballona, consistent with its urban surroundings.

50E. THE EFFECTS OF AGE AND SEXUAL EXPERIENCE ON THE MATING SUCCESS OF THE MALE HOUSE CRICKET, *ACHETA DOMESTICUS*

E.S. Peralta and S.E. Walker. Southern California Ecosystems Research Program, California State University, Fullerton, Department of Biological Science, Fullerton, CA, 92831

Age and sexual experience are factors that have rarely been studied in insects. House cricket (*Acheta domesticus*) males have been studied extensively in regards to what type of acoustic signals females choose. However, acoustic signals are long-distance and are only part of the process of mate choice. During courtship, when the male is close to the female, numerous other factors could influence male success. We examined how male age and sexual experience impact mating success. We hypothesized that older males will have higher mating success than younger males and that sexually experienced males will have higher mating success than males with no experience. In the first experiment, virgin males of different ages were paired with virgin females. In the second experiment, males with varying sexual experience were paired with virgin females. Prior to this experiment, sexually mature males were placed in one of two treatments for 48 hrs with virgin females: 0 female partners or 2 female partners. After this period, the males were isolated for 48 hrs before being presented with a virgin female for observation. In each experiment, we measured the number of successful matings, duration of successful matings, number of attempted matings, and time until mating for the males. Results will be discussed in regard to mate choice in crickets and sexual selection.

51E. METAL CONCENTRATIONS IN *MACROCYSTIS PYRIFERA* BETWEEN THREE DEPTHS AT LA HARBOR AND EAGLE ROCK

M.R. Raith and A.Z. Mason. Manley Lab Group, CSU, Fullerton and CSU, Long Beach, Department of Natural Sciences and Mathematics, Long Beach, CA, 90840

Metal pollution is a significant problem in coastal marine communities that receive urban run-off and discharges. The following study aims to establish if the concentrations of metals within the sieve tube sap (STS) of the kelp *Macrocystis pyrifera* can be used to monitor the bioavailability and origin of metals within marine ecosystems. Inductively coupled plasma mass spectroscopy was used to compare the metal concentrations of kelp STS collected from a reference site at Eagle Rock on Catalina Island and fronds collected from LA Harbor, which is known to experience significant anthropogenic inputs of metals. STS was collected from 0 m (surface), 5 m and 10 m down the length of the frond. It was hypothesized that greater concentrations of metals would be present in LA harbor and if differences between depths occurred, the highest concentrations would occur at the apex of the frond since this region contains the highest levels of photosynthetates. Zinc, barium, cesium, rubidium, vanadium, and mercury were found in significantly higher concentrations at LA Harbor while cadmium, strontium and silver were significantly elevated in the fronds from Eagle Rock. Cadmium was also found to differ significantly between depths with the highest concentrations at 5 m and 0 m at both sites. The elevated Cadmium in the kelp from Eagle rock was attributed to seasonal upwelling and the high levels of bird guano found proximal to this site.

52E. SETTLEMENT OF *OSTREA CONCHAPHILA* AS A FUNCTYION OF TIDAL HEIGHT IN A SOUTHERN CALIFORNIA

L.A. Sam and D.C. Zacherl. California State University, Fullerton. Department of Biological Science

Recent interest in restoration of *Ostrea conchaphila*, the native west coast oyster, motivates an interest in understanding factors influencing population persistence. Not only survival of adults, but also settlement of spat can affect the persistence of future generations. Processes controlling settlement dynamics of this species are of particular concern because we can exploit natural settlement of spat for seeding restoration habitat. Here, we examined the effect of tidal height on settlement rates in Newport Bay, CA using replicate stationary PVC arrays ($n=4$) that suspended PVC tiles at different tidal heights during two consecutive tide series. Settlement varied inversely with tidal height (Two-way ANOVA, $p<0.0001$) and

among tide series (p=0.02). Results from this study also suggested that tile distance from the mudflat bottom may be more important than tidal height in determining settlement rates. Further studies will aim to tease out the relative importance of these two factors.

53E. SONG PLAYBACK EXPERIMENTS IN ANNA'S AND COSTA'S HUMMINGBIRDS

B.R. Williams, C. Castro, and A.M. Houtman. California State University, Fullerton, Department of Biology, Fullerton, CA, 92831

Hummingbirds, like songbirds, learn and sing complex songs. However, it is not known if song plays a role in individual recognition in hummingbirds. The *Calypte* genus has two species: Anna's hummingbird (*Calypte anna*) which has a complex, learned song and Costa's hummingbird (*Calypte costae*) with a relatively simple song. These structural song differences may indicate differences in the use of song between these two species. Neighbor-stranger playback experiments have documented individual recognition in territorial males in many songbird species. We conducted neighbor-stranger and heterospecific playbacks to Anna's and Costa's hummingbirds during the breeding season in Anza Borrego State Park, California (2007) and currently near Palm Desert, California (2008). The playbacks consisted of four trials in random order: a neighbor song, a stranger song, the sister species' song (a heterospecific competitor) and a heterospecific non-competitor's song. The results from our first season suggest that Anna's hummingbirds respond more aggressively to conspecific than heterospecific playback. Costa's hummingbirds showed no apparent response to conspecific playback during the first season of trials, but preliminary results from this season suggest that they are responding more aggressively to conspecific playback. To date there is no strong evidence for neighbor-stranger discrimination in Anna's or Costa's hummingbirds. Data collection is being continued during the 2008 breeding season. This is the first known study examining neighbor-stranger recognition in hummingbirds.

54F. LASER ABLATION ICP-MS ANALYSIS OF PREHISTORIC AND CONTEMPORARY WHITE CROAKER (*GENYONEMEUS LINEATUS*) OTOLITHS

James F. Harwood. California State University, Bakersfield, Department of Biology, Bakersfield, CA 93311

Fish otoliths (ear stones) absorb metals and other elements from their surroundings as they grow throughout life. I used laser ablation inductivity coupled plasma mass spectrometry (LA-ICP-MS) to compare the ratios of trace metals and several other elements in contemporary and prehistoric otoliths from the white croaker (*Genyonemus lineatus*). The goals of this study were to determine if LA-ICP-MS of fish otoliths could be a viable method of determining changes in ocean chemistry over time, and to observe any increases in anthropogenic elements associated with modern industrial practices in the contemporary otoliths. I obtained prehistoric otoliths from an archaeological deposit dated to be 6,000 to 600 years old, near Seal Beach, California (ORA-263). Contemporary otoliths were obtained using hook and line bait fishing from the pier at Seal Beach. The growth rings of these otoliths were exposed by cutting otoliths in half that were embedded in resin. I took LA-ICP-MS readings from the center to the outer rings of the otoliths. I determined the element to Ca ratio for each element being analyzed. A two way ANOVA revealed that most of the elements were found at higher ratios in the prehistoric otoliths than in contemporaries.

55. VARIATION IN THE DEEP SEA HOLOTHURIAN *PSYCHROPOTES LONGICAUDA* AND CONFIRMATION OF THE SPECIES *PSYCHROPOTES MIRABILIS*

K.D. Trego. Nautilus Oceanic Institute, La Jolla, CA 92037

The deep sea holothurian *Psychropotes longicauda* is found at depths of 1000 to 6000 meters and is cosmopolitan in distribution. It is the most widely distributed of the deep sea holothurians seen in benthic imagery. *Psychropotes longicauda* is an extremely variable species in both morphology and color. The species *Psychropotes mirabilis* was described from a single specimen from the Indian Ocean. *Psychropotes mirabilis* is very similar to *P. longicauda* with the primary difference being a two lobed dorsal appendage while that of *P. longicauda* has a single lobe. A second specimen of *P. mirabilis* has been seen in benthic imagery of the abyssal plain of the Indian Ocean. There is a clear difference in the structure of the dorsal appendage of the *P. mirabilis* seen in the benthic imagery and those of *P. longicauda* seen in the same benthic imagery. Detection of the second *P. mirabilis* individual confirms the status of the species.

56. ECOSYSTEM IMPLANTATION ON SATURN'S MOON TITAN BY ACCUMULATION OF INTERNAL OCEAN SATELLITE ICE DEBRIS CONTAINING ORGANISMS

K.D. Trego. Nautilus Oceanic Institute, La Jolla, CA 92037

Microbe containing ice may originate in Saturn's planetary system from the disintegration of ice satellites with internal ocean ecosystems. Icy moons with internal oceans, which previously existed in orbit around Saturn, could have been destroyed through tidal disruption by Saturn or by collision with other moons, asteroids, or comets. Also, microbe containing ice may be ejected into Saturn's E ring by the plumes of Enceladus which may have or may have had an internal ocean with an ecosystem. Water ice makes up 90% of the plume material being ejected from the south polar fractures on Enceladus. Some of the water ice crystals are deposited on the surface of Enceladus while the rest ends up in the E ring of Saturn. This ice with microbes in the Saturnian system may be accumulated by the existing moons of Saturn. There is evidence of accumulated debris in the Saturnian system by Saturn's moons Iapetus, Hyperion, Atlas and Pan. The only moon of Saturn where microbes from ice debris could survive and implant an ecosystem would be Titan. Microbes would have to make a transition from an internal water ocean ecosystem to an external hydrocarbon ocean ecosystem on Titan.

57. TRANSIENT MACROFAUNA INVERTEBRATES IN THE CHALLENGER DEEP ECOSYSTEM OF THE MARIANAS TRENCH

K.D. Trego. Nautilus Oceanic Institute, La Jolla, CA 92037

Benthic imagery of the Challenger Deep ecosystem of the Marianas Trench at 10,900 meters may imply that species of macrofauna invertebrates are transient in the deepest ecosystem of the world's oceans. JAMSTEC imagery taken by the ROV Kaiko observed the rare presence of the pelagic amphipod *Hirondellea gigas* and a species of the holothuroid genus *Peniagone*. A species of the actinarian anthozoan genus *Galatheanthemum* is not seen in benthic imagery although it was trawled in the Marianas Trench at a depth of 10,730 meters. Macrofauna species in the Marianas Trench may be transient to the Challenger Deep ecosystem while some smaller infaunal invertebrates, such as the small holothuroid *Prototrochus brunni*, may be more permanent species of the Challenger Deep ecosystem.

58. THE GENERATION OF QUENCHED ENCLAVES DURING MAGMA MINGLING OF MAFIC MAGMAS: EXAMPLES FROM THE SIERRA NEVADA AND THE SOUTHERN CASCADES

B.L. Browne, A. Steiner, M. Van Ry, and P. Saleen. Cal State Fullerton Department of Geological Sciences, Fullerton, CA, 92834

The presence of quenched mafic enclaves in igneous rocks is well documented in andesitic to rhyolitic host lavas and domes as well as in the plutonic record. These enclaves form by the mingling in the liquid state of coexisting magmas with strongly contrasting physical properties, as indicated by textural evidence such as a spherical or ellipsoidal shape with vesicular interiors, acicular groundmass minerals and/or cuspate margins. Interestingly, evidence for basaltic enclaves forming in basaltic or basaltic andesite host magmas lavas is virtually absent in the scientific literature. Of course, the fact that basaltic enclaves rarely are observed in mafic host lavas does not preclude the occurrence of basalt-basalt magma mixing, but rather underscores the importance that contrasting physical properties (i.e. viscosity) in the interacting magmas play in the formation of quenched enclaves. This study presents findings on the morphologic and petrologic characteristics of basaltic enclaves in basaltic and basaltic andesite host lavas as a means of constraining the manner in which mafic enclaves form in host magmas of similar viscosity, temperature, and composition. Here, we show that mafic enclaves in mafic hosts are typically small (<3 cm), subrounded, composed almost entirely of plagioclase and orthopyroxene with rare clinopyroxene and olivine, and exist in close proximity to the erupting vent. Their texture and crystal morphologies are characterized by radiating and acicular plagioclase, vesicular groundmass, and fine-grained margins, consistent with a magma-mixing origin between a basaltic magma intruding into a slightly lower-temperature basaltic-andesitic reservoir.

59. TURONIAN TO CAMPANIAN LAVAS FROM SOUTHWEST PUERTO RICO AND THE TIREO GROUP OF SOUTH CENTRAL HISPANIOLA (GREATER ANTILLES ISLAND ARC): IDENTIFICATION OF AN UPPER CRETACEOUS ISLAND ARC

Johannes H. Schellekens[1] and Wayne T. Jolly[2]. [1]temporarily Dept. of Geological Sciences, California State University, San Bernardino CA; [2]Department of Geological Sciences, Brock University, St. Catharines, Ontario L2O 3A1

Temporally equivalent Turonian to Campanian island arc strata are present in southwest Puerto Rico and in south central Hispaniola. The Puerto Rican strata occur in a northwest-trending belt that contains on the southwest flank lavas from the forearc, consisting of clinopyroxene (cpx)-plagioclase (pl)-hornblende (hb) basalts and cpx-pl-orthopyroxene (opx) high-Mg andesites, and on the northeast flank lavas from the principal volcanic axis, consisting of cpx-pl basalts. Geographic arrangement of rock types indicate the strata were produced in a northeast-dipping subduction zone. Incompatible element-enriched compositions of the Puerto Rican lavas are consistent with melting in an E-MORB-type mantle wedge source that was enriched by emplacement of the Caribbean Cretaceous mantle plume during Turonian times (91–88 Ma) immediately preceding arc volcanism. Turonian to Campanian strata from the Upper Tireo Group in south central Hispaniola include incompatible element-depleted basalts, identified as boninites, high-Nb basalts, and low-Al_2O_3, low LREE dacites and rhyolites, identified as low-pressure crustal melts. Incompatible element concentrations in the boninitic basalts, high-Nb basalts, and dacites and rhyolites are consistent with an E-MORB-type source, and with northeast-dipping subduction as in southwest Puerto Rico, suggesting a single island arc possible continuing into the Aves Ridge island arc.

60P. GRANDE SOUFRIERE HILLS VOLCANO, DOMINICA, LESSER ANTILLES

G.E. Daly[1], A.L. Smith[1], M.J. Roobol[2], and J.E. Fryxell[1]. [1]Department of Geological Sciences, California State University, San Bernardino, CA 92407; [2]Saudi Geological Survey, Jeddah, Saudi Arabia

The Grande Soufrire Hills volcano is deeply dissected, but has a distinct circular crater that opens to the east within which is a lava dome. Unconsolidated pyroclastic deposits which mantle the southeast flanks of the volcano are almost entirely block and ash flows and surges suggesting that Pelean-style eruptions, dated between 10,000 to 12,000 years, have dominated its most recent activity. On the southeastern coast at Pointe Mulâtre and extending approximately 4 km north and 2 km west, is a megabreccia of large flow-banded andesite clasts set in a semi-lithified medium-grained ash matrix. At Pointe Mulâtre this megabreccia is overlain by unconsolidated block and ash flow deposits. To the north of the megabreccia, exposures in the sea cliffs reveal a consolidated sequence of well-bedded alternating coarse and fine deposits suggesting deltaic beds, which in turn appear to be overlain by a yellow-colored relatively coarse flow deposit with an irregular upper surface, that may represent a debris avalanche deposit associated with the collapse of the eastern flank of the volcano. The uppermost deposits in the sea cliffs are a sequence of block and ash flow deposits and interbedded fluviatile conglomerates equivalent to the younger flow deposits logged inland, that have given 14C ages of around 11,000 years B.P.

61P. A STUDY OF GEOTHERMAL SPRINGS IN NORTHERN DOMINICA

S. Harrell, A.L. Smith, E. Melchiorre, and J.E. Fryxell. Department of Geological Sciences, California State University, San Bernardino, California, 92407

The geochemistry of two groups of geothermal springs located in the north of Dominica, Lesser Antilles were studied over a four year period. One group, the Penville Cold Soufriere, is located in the summit region of the potentially active Morne aux Diables volcano, the other group, which comprises both submarine and subaerial springs, is located in the vicinity of Portsmouth, the second largest town on the island, and on the flanks of Morne Diablotins, a second potentially active volcano. The chemistry of these springs was compared to "reference standards" composed of average seawater, seawater from Prince Rupert Bay (adjacent to Portsmouth), a fresh water pool in the center of the island and rainwater. A group of 21 elements in the hot springs consistently showed greater than two-orders of magnitude difference to the "reference standards". When these elements are plotted on chemical variation diagrams the springs and the reference standards form two trends, one composed of the submarine springs and the seawater compositions and the other the subaerial springs and the freshwater compositions. For many elements these two trends intersected at a point that is interpreted to represent the original composition of the geothermal waters before dilution with either seawater or meteoric water. Oxygen and hydrogen isotopic compositions also suggest for many springs a mixing of a magmatic source with either meteoric water or seawater.

62. GEOLOGICAL EVOLUTION OF DOMINICA, LESSER ANTILLES

A.L. Smith[1], M.J. Roobol[2], J.E. Fryxell[1], and L. Fernandez[1]. [1]Department of Geological Sciences, California State University, San Bernardino, CA; [2]Saudi Geological Survey, Jeddah, Saudi Arabia

The geology of the Dominica can be divided into 4 units: Miocene; Pliocene; 'Older Pleistocene'; 'Younger Pleistocene'-Recent. The Miocene rocks are only exposed along the east coast. Separated from the Miocene by a major unconformity are a number of eroded stratovolcanoes of Pliocene age often composed of pillow lavas and submarine volcanic breccias, overlain by subaerial lava flows interbedded with pyroclastic deposits. The centers of Morne aux Diables and Morne Diablotins are confined to the N of the island and are characterized by the presence of Pelean domes and associated aprons of block and ash flow deposits. Around 1 Ma activity switched from the N to the S, where six major volcanoes, (Morne Trois Pitons, Wotten Waven/Micotrin, Watt Mountain, Grand Soufriere Hills, Morne Anglais, and Morne Plat Pays) developed. Activity also continued in a reduced manner at the two northern centers. Within the last 100,000 years, 3 major periods of Plinian activity produced extensive subaerial and submarine pumiceous deposits. These eruptions, each of which is estimated to have produced tens of km^3 of pyroclastic material are associated with Morne Diablotins, and the calderas of Morne Trois Pitons and Wotten Waven/Micotrin. Morne Plat Pays in the SW corner of the island has also been subjected to at least 3 sector collapses during the past 300,000 years. Recent eruptive activity have been associated with centers within the sector collapse and the Watten Waven caldera.

63E. GENETIC VARIATION AND SYSTEMATIC DIVERSITY IN THE AMPHIPOD GENUS *CYAMUS*, USING MITOCHONDRIAL AND NUCLEAR GENE SEQUENCE ANALYSIS

Tishy-Linda M. Bunk. Biological Sciences, Cal. State L.A. Los Angeles, CA 90032-8201

Taxonomy of cyamids, amphipod ectoparasites found on cetaceans, has been problematic and confusing. The most abundant genus *Cyamus* is considered to comprise 12–13 species, according to a recent taxonomic revision (Haney, unpublished), but molecular data are needed to support these conclusions. The present study will analyze the phylogeny of the genus based on DNA sequence analysis of mitochondrial cytochrome c oxidase I (CO1) and the 16S and 28S nuclear rRNA. *Cyamus* will be analyzed and the resulting phylogenetic tree(s) will be compared with previous taxonomic hypotheses. The goal is to generate a molecular phylogeny and resolve relationships within the genera *Cyamus*. In the future, the phylogeny obtained here may contribute to other studies such as divergence time analysis, which may clarify cyamid diversification in relation to host species. Cyamid phylogeny offers another look into whale history, which is especially useful because whales have comparatively little intraspecific variation in molecular markers.

64. GENETIC CONFIRMATION OF HYBRIDIZATION BETWEEN *CATOSTOMUS FUMEIVENTRIS* AND *CATOSTOMUS SANTAANAE* (CYPRINIFORMES: CATOSTOMIDAE) IN THE SANTA CLARA DRAINAGE

D.G. Buth[1], **J. Sim[1]**, and C.C. Swift[2]. [1]Dept. of Ecology and Evolutionary Biology, UCLA, Los Angeles, CA 90095-1606; [2]ENTRIX, Inc., 2140 Eastman Avenue, Suite 200, Ventura, CA 93003

The presence of morphoplogical intermediates has suggested that *Catostomus fumeiventris* and *C.santaanae* hybridize in the Santa Clara drainage where both were introduced many decades ago. We used starch gel electrophoresis of codominant gene products to confirm the genetic interaction between these two species of fishes. Both F_1 and F_2 generations of hybrids were identified, but both parental species still maintained their genetic integrity. Of 160 specimens obtained from Sespe Creek north of Fillmore CA on 15 May 2006, 125 were genetically identified as *C. santaanae*, 11 as *C. fumeiventris*, 10 as F_1 hybrids and 14 as F_2 hybrids. The F_2 hybrids appeared to be the progeny of $F_1 \times F_1$ crosses or backcrosses to *C. santaanae*.

65E. OBSERVING THE EFFECTS BIOFILMS, PLANTS AND SEDIMENTS HAVE ON CONCENTRATIONS OF NITRATE AND PHOSPHATE IN WATER SUPPLIES

John Campo and Genevieve Ryan. Pasadena City College, Sustainability Studies Research Group, Pasadena, CA, 91106

The focus of this investigation is the use of artificial wetlands and local biofilms to reduce phosphate and nitrate pollutants from a contaminated water supply. Biofilms, plants and sediments that have been historically exposed to high levels of nitrate and phosphate contamination were collected and placed in a manufactured environment that mimicked a wetland but allowed for control of input, output and flow rates. Different combinations of treatments were tested and several different flow rates to examine the effects of each aspect and find the optimal combination for removing the targeted pollutants. The tests produced variable results for the concentrations of nitrate. There was a consistent pattern of phosphate reduction through the entire test.

66. COYOTE AND FOX ON THE PALOS VERDES PENINSULA

A. Dalkey[1], K. Gallagher[2], K. Bailey[3], Elaine Chow[3], K. Lyberger[3], B. Niemiec[4], and N. Wakayama[3]. [1]Palos Verdes Peninsula Land Conservancy, 916 Silver Spur Road #207, Rolling Hills Estates, CA, 90274; [2]Biology Department, California State University Long Beach, Long Beach, CA, 90840; [3]Palos Verdes Peninsula High School Rolling Hills Estates, CA, 90274; [4]Chadwick School, Palos Verdes, CA, 90274

The Palos Verdes Peninsula Land Conservancy has an on-going study of coyote (*Canis latrans*), red fox (*Vulpes vulpes*), and gray fox (*Urocyon cineroargenteus*) on the Palos Verdes Peninsula. It is a collaborative effort, involving high school and college students who gain biological survey experience as well as credit for school research. Additionally, this project enables the Conservancy to satisfy a monitoring requirement for the Palos Verdes Nature Preserve's Natural Communities Conservation Plan (NCCP). This study was initiated to determine major and minor movement corridors of these three species. Each participant selected a specific location to regularly survey for scat and tracks. The predominant observation was scat, which can be used to distinguish coyote from fox. Tracks are unique for each species, but were rarely observed. When found, tracks were measured and photographed. Data were collated, normalized to adjust for variation in survey frequencies, and mapped to illustrate location and number of observations for the six-month period from November 2007 through April 2008. As expected, areas having better quality habitat were more frequently visited. Conversely areas surrounded by higher density housing had lower visitation rates. Patterns of scat deposition show a preference for level ground with coyotes favoring trail junctions and fox using trail sides within 50 m of trail junctions. Most interesting is that all locations are heavily used by hikers, runners, and domestic dogs illustrating the tolerance for urban life that these animals have developed

67E. ABOVE AND BELOWGROUND FEEDBACKS FOLLOWING EXOTIC PLANT INVASION AND RESTORATION OF COASTAL SAGE SCRUB OF SOUTHERN CALIFORNIA

S.J.M. Dickens and E.B. Allen. Department of Botany and Plant Sciences, University of California Riverside, Riverside CA 92521

The invasion of exotic plants into coastal sage scrub has increased displacement of rare and endangered species, fire hazard due to their higher density and flammable biomass, and an alteration of important above and belowground processes that promote healthy ecosystem function and species diversity. In order to understand the impact exotics have on these processes and the potential for restoration after invasion, research must address changes in both the above and below ground processes being altered. Historically restoration efforts focused on aboveground native vegetation with less emphasis on the soil system. Few studies have looked at restoration of invaded soil. Therefore, it is not known if soils and their processes recover from exotic plant invasions once the invaders have been removed and native plants restored. This work examines how the presence of exotic plant species changes soil characteristics, how these changes may be maintaining the presence of exotics by negatively affecting native species and whether these changes are reversible through vegetation restoration and exotic plant removal. Three hypotheses are being tested: **(1)** the presence of exotic plant species changes the characteristics of the soils beneath them. **(2)** If exotics are controlled and natives restored, soil characteristics will return to pre-invaded conditions. **(3)** Changes in soil due to the presence of exotic species have negative impacts on native species grown in invaded soil.

68E. THE EFFECTS OF NITROGEN ADDITION AT DIFFERENT STAGES OF DECOMPOSITION

M. Greas, D. LeBauer, and K. Treseder. University of California, Irvine, Department of Ecology and Evolutionary Biology, Irvine, CA, 92697

Many fungi and bacteria decompose organic material faster under nitrogen enrichment. However, microbial activity may be negatively affected if levels of nitrogen are exceptionally high for prolonged periods. We compared N effects on decomposition of fresh litter, old litter, and older, more-decomposed litter (i.e., "light fraction"). We hypothesized that as N addition rates increase, decomposition of fresh litter and old litter will increase to a maximum value, and ultimately decrease. We expect decomposition rates of light fraction to decrease initially and eventually level off. To test our hypothesis, we constructed a microcosm experiment with litter collected in 2007 from a California grassland. Litter was incubated for 90 days under four levels of N addition. Respiration of carbon dioxide was collected as an indicator of decomposer activity. We also measured the carbon and N content of the litter to determine if N responses are related to C:N ratios. Typically, C:N ratios of litter strongly control decomposition rates, and we expect that N additions will essentially shift these ratios. Different substrates decomposed at different rates ($P<0.0001$) and responded differently to N ($P=0.016$). Decomposition of light fraction increased approximately 20% as nitrogen levels increased ($P=0.031$). As for old litter, there was no effect of nitrogen on decomposition. The decomposition rate of new litter declined by 30% at the lowest level of nitrogen addition but increased to control levels at higher rates of nitrogen ($P=0.0042$). Our data suggest that effects of nitrogen addition vary depending on stage of decomposition.

69. PROTOCOLS FOR *HALIOTIS RUFESCENS* EGG CRYOPRESERVATION AND *IN VITRO* FERTILIZATION (YEAR 2)

Julie A. Guerin. Cabrillo Marine Aquarium, San Pedro, CA 90731; Palos Verdes Peninsula High School, Rolling Hills Estates, CA 90274

Gamete cryopreservation can play an important role in conservation strategies for at-risk abalone species. Objectives of this study were to continue investigating red abalone egg cryopreservation protocols by determining whether eggs which exhibit normal phenotypes after thawing could be successfully fertilized with live sperm, and by evaluating propylene glycol (PG) as an alternative cryoprotectant agent (CPA) to dimethyl sulfoxide (DMSO).

After induced spawning and egg collection, eggs were frozen using cooled or uncooled DMSO or PG at 8 and 16 mins stepwise cooling at 14, ≤4, −40 degrees C, before plunging into liquid nitrogen. 26 stepwise thawing protocols (5 mins at −40, ≤4, 14 degrees C with 1.25 g or 2.5 g non-permeating sucrose/80 ml

water) and 20 *in vitro* fertilization tests were conducted. Protocols using PG at 8 or 16 mins stepwise cooling and stepwise thawing with 1.25 g sucrose, yielded 90% to100% (8 mins) and 75% to 80% (16 mins) intact round eggs with clear chorion. PG protocols using 2.5 g sucrose during thawing yielded less than 10% such eggs. DMSO stepwise cooling (8 and 16 mins) and stepwise thawing (1.25 g or 2.5 g sucrose) protocols yielded 10% to 25% intact round eggs displaying little or missing chorion. Sperm orientation towards eggs during *in vitro* fertilization attempts occurred only in PG trials. No cell division occurred. PG appears to be the more effective CPA, as chemical signaling between sperm and eggs, with release of egg chemoattractant (L- tryptophan), remained bioactive after cryopreservation. CPA toxicity, ice crystallization or other factors may have caused egg damage and prevented fertilization. Further research will involve refining protocols.

70E. THE EFFECTS OF DISTURBANCE OF BIOLOGICAL SOIL CRUSTS ON THE GERMINATION OF EXOTIC PLANTS IN COASTAL SAGE SCRUB

Rebecca R. Hernandez and Darren Sanduist. Department of Biological Science, California State University, Fullerton, CA 92831

Invasion by nonnative species is shifting the composition of coastal sage scrub (CSS) plant communities in southern California from native perennial shrubland to exotic annual grassland. Disturbance of the soil, and especially, biological soil crusts (BSCs), is known to increase germination of exotic plants. These crusts, which are a fragile aggregation of cyanobacteria, fungi, green algae, lichen, and moss, occupy the soil surface, and perform key ecosystem functions in both high and low abiotic stress environments, including CSS. Using a field and greenhouse experiment, I tested the hypothesis that disturbance of BSC increases germination of exotic plants in CSS plant communities. At Whiting Ranch Wilderness Park in Lake Forest, California, 21 paired plots were established and mean germination of exotic and native plants was compared between control subplots containing intact BSC and disturbed subplots. In the greenhouse experiment, BSC cores were removed from Whiting Ranch and half were disturbed. Seeds of native and exotic plant species were placed in the BSC cores, watered for 8 weeks, and then observed daily to determine emergence (n=6). In the field, disturbance of BSC significantly increased mean exotic germination and mean germination of native species was higher in undisturbed BSC. In the greenhouse, percent emergence was higher in disturbed BSC cores for all species and mean day of emergence was species specific. These results will assist land managers to better manage and preserve CSS communities by including BSC as an ecological factor affecting exotic plant invasions and a component of overall ecosystem health.

71E. ETHYLENE, TEMPERATURE, AND LIGHT EFFECTS ON THE GERMINATION OF THE SAND VERBENA, *ABRONIA MARITIMA* S. WATSON

Kristine Tulio, Noel De Leon, and Philippa M. Drennan. Loyola Marymount University, Department of Biology, Los Angeles, CA 90045

Abronia maritima S. Watson is a sand verbena native to coastal dunes of Southern California and Mexico. Germination percentages of *Abronia* species in the laboratory are low. This research aims to develop techniques of germinating *A. maritima* for restoration of dune vegetation, and to elucidate environmental factors resulting in germination. Germination studies were performed under controlled conditions, using various temperatures, with or without the addition of ethylene (supplied as ethephon), which has been shown to overcome dormancy. Anthocarps were removed from achenes for all trials. A dose response experiment showed that imbibition of achenes in 100 μ mol l^{-1} ethephon optimized both germination rate and percentage. At constant temperatures and 100 μ mol l^{-1} ethephon, germination was optimal at 20°C, and decreased above 35°C and below 15°C. Across the same range of constant temperatures, little to no germination occurred for achenes imbibed in water and kept in the light. Furthermore, neither cold nor warm stratification significantly increased germination in the absence of ethephon. However, achenes showed increased germination under alternating temperatures (15/35°C for 12/12 h) from 26% in the light, to 58% in the dark without ethephon. These results suggest *A. maritima* is negatively photoblastic, but may not germinate if buried too deeply or in areas where shading reduces soil temperature variation. Temperatures of sandy substrates in habitats typical for *A. maritima* are being continuously monitored using data loggers. Additional experiments are testing the effects of burial depth and the role of sand in stimulating germination.

72E. EFFECTS OF SMALL-SCALE DISTURBANCE ON SEED BANK SPECIES IN A COASTAL SAGE SCRUB COMMUNITY

F.D. Herrera. Biological Sciences Department, California State Polytechnic University, Pomona, CA, 91768

California Coastal Sage Scrub (CSS) is a biologically diverse community in a Mediterranean environment. Species have adapted to germinate, survive and reproduce in an environment prone to seismic activity, drought and periodic fire and thus the Coastal Sage Scrub shows resilience to large-scale disturbance. Such large-scale disturbance events are believed to be required for long-term maintenance of a healthy CSS community, but there is evidence to suggest that disturbances that occur between larger events play a significant role in the persistence of CSS. These smaller-scale events may include soil disturbances, litter disturbances, and canopy disturbances that result from animal activity, stochastic events, or anthropogenic causes. This study observed the effects of small-scale disturbances on the seed bank species at the Voorhis Ecological Reserve. I determined the impact of soil, litter and canopy disturbances on germination and survival of focal seed bank species and considered possible implications for the role of small-scale disturbance in maintaining Coastal Sage Scrub communities in Southern California. Preliminary analyses indicated that very few native species were recruited and non-native annuals persisted longer in a drought year across all disturbance treatments. Additionally, *Centaurea melitensis* and *Hirschfeldia incana* successfully germinated and persisted to flowering in an extremely dry year. The results of this study may be significant in understanding the implications of small and large-scale disturbances on the persistence of viable CSS communities.

73E. EFFECTS OF LIGHT AND COLUMN HEIGHT ON DIEL VERTICAL MIGRATION OF THE MARINE GASTROPOD *KELLETIA KELLETII*

S.L. Kelley, C.J. Cortez, W.J. Hoese, and D.C. Zacherl. California State University, Fullerton, Department of Biological Science, Fullerton, CA 92831

Marine veliger *Kelletia kelletii* larvae exhibit diel vertical migratory (DVM) behavior; larvae ascend at night and are demersal during the day. DVM behavior has strong implications for larval dispersal outcomes. We investigated how light and vessel height influenced DVM behavior and whether DVM patterns in the lab were similar to those in the field. We hypothesized that DVM behavior would be light-initiated and would not be affected by column height, and that field surface densities of *K. kelletii* larvae would be higher at 2400 h than at 1200 h. We placed 100 larvae in replicate cultures ($n = 4$) under two different light treatments, natural (16:8) and a dark-only photoperiod (0:24), and two different column treatments (15 and 125 cm). Vertical positions in the column were recorded every 4 h for 24 h. Surface plankton tows ($n=3$) were conducted at 1200 h and 2400 h of the coast of Palos Verdes, CA. Column height and the interaction between photoperiod and time were significant (3-way full-factorial ANOVA for photoperiod, column height and time). Cultures in shorter columns had significantly greater proportions of demersal larvae. During daytime, natural photoperiod treatments had higher proportions of demersal larvae than dark-only treatments. Plankton tows revealed significantly higher densities of total veligers (2-sided F-test, $n=3$) and similar trends for *K. kelletii* (T-test, $n=3$) at the surface at 2400 h compared to 1200 h. Unraveling DVM behavior in *K. kelletii* larvae can aid in understanding distributional patterns of adults.

74E. PLANT ABSORPTION OF THE CHEMICAL POLLUTANTS NITRATE AND AMMONIA

Niree Kodaverdian, Pwint Khine, Steven Do, Jason Diep, Jimmy Lau, and Kyaw Lynn. Sustainability Studies Research Group, Pasadena City College, CA 91106

In Hahamongna Watershed Park (Pasadena, CA.) chemical pollutants from the runoff from equestrian centers have been implicated in contamination of the surface and possibly ground water supplies. We tested the effect of local native plants on the concentrations of pollutants from the effluent of local stables. We isolated several species of plants and tested them separately to make recommendations on using them for possible bioremediation. The main pollutants from the effluent were nitrate and ammonia and cattails (*Typha latifolia*) had the most prominent effect reducing the targeted pollutants. We suggest designing the landscape around the equestrian outfalls to maximize contact between the effluent and plants that remove nitrate and ammonia.

75. USING HISTORICAL TAGGING DATA (1962–1971) TO ANALYZE THE SPAWNING RELATED MOVEMENTS OF BARRED SAND BASS, *PARALABRAX NEBULIFER* (SERRANIDAE) IN SOUTHERN CALIFORNIA

C. Linardich, E.T. Jarvis, C.F. Valle, and P. Young. California Department of Fish and Game, Marine Region, Los Alamitos, CA, 90702

Southern California recreational fishers target barred sand bass, *Paralabrax nebulifer*, during the summer months when the fish form large spawning aggregations. Despite its popularity as a sportfish, very little information is known regarding the spawning-related movements of barred sand bass. However, from 1962–1971, biologists with the California Department of Fish and Game tagged over 4,000 barred sand bass within the Southern California Bight. Tagging primarily occurred on historical spawning grounds during spawning season (Apr. to Oct.), except for those fish tagged year-round in Newport Harbor. Our objectives were to examine these historical data for trends in 1)residence times on spawning grounds, 2)movement to non-spawning season residences, and 3)spawning site fidelity. Of the tagged barred sand bass, 749 were recaptured within a maximum of 1,211 days at liberty. Recaptures within a spawning season showed an approximate residence time of two months at the tagging location. The farthest recapture distance was 66 km. Recapture distances during non-spawning season were variable, suggesting that the proximity to non-spawning season residences may vary greatly by individual fish regardless of the locality of their spawning ground. Annual seasonal patterns in recapture locations from Huntington Flats (a summer season tagging location) and Newport Harbor (a winter season tagging location), strongly suggest both spawning and non-spawning season site fidelity. Although obvious caveats exist within tag and recapture studies, these data are valuable for future studies on finer scale spawning-related movements of barred sand bass.

76E. POST-FIRE PLANT SUCCESSION AT TUCKER WILDLIFE SANCTUARY IN MODJESKA CANYON, CALIFORNIA

V. Lopez, S. Simjee, W.J. Hoese, and D.R. Sandquist. Department of Biological Science, California State University Fullerton, Fullerton, CA 92834

We observed succession of a chaparral plant community following the October 2007 Santiago Fire. The study site was a burned south-facing hillside at Tucker Wildlife Sanctuary (Modjeska Canyon, CA) that included four microhabitats: ridge, open slope, canopy-covered slope, and drainage. Each microhabitat consisted of five, one-meter square plots, haphazardly spaced, that were photographed monthly starting in January 2008. Plant abundance, species richness, and percent cover were measured from photographs of each plot to assess differences in post-fire recovery across microhabitats. Preliminary analyses show an increase in vegetative cover in all plots due to resprouts or recruitment of seedlings. We observed the greatest percent cover in the canopy-covered slope microhabitat. The other three microhabitats exhibited variability in percent cover, however, such cover was uniformly low. These observations suggest that soil nutrient content and propagule presence was greater in the canopy-covered slope microhabitat.

77E. QUESTION REALITY: QUALITATIVE INTERPRETATIONS OF UNIVERSAL SCALING LAWS IN BIOLOGY-ECOLOGY-EVOLUTION

V.G. Minnich and M.L. Droser Advisor. Department of Earth Sciences. University of California, Riverside, 92521

There have been recent breakthroughs in discovering mathematical scaling laws in biology and ecology by a small team of scientists (West, Brown, Enquist, et alia). Though there has been extensive data crunching and mathematical exploration of the transcendence of these scaling patterns across multitudes of biological systems, there has been little philosophical, scientific, and artistic investigation of the qualitative meanings of these laws, and their implications for restructuring/re-organizing the entire way how we understand biological reality. Primarily, these mathematical principles provide the license to apply spacetime reasoning and a constructionist approach—the mental organizing tools of geology and film—into the overarching discipline of biology. This poster will touch on the main themes and applications of scaling laws to qualitative re-structuring of ecological systems on planet Earth at multiple scales: from deep to present times, from non-human to human systems, and even to providing implications in the realm of constructing and managing human-environmental systems for short- and long-term sustainability. The products of this poster will be submitted to the international STAGE script competition at UC Santa Barbara, a contest involving artistic, creative story-telling for science and technology, such as to communicate academic ideas to wider audiences.

78P. PALEO GROUNDWATER CHEMISTRY RECORD FROM FAULT ZONE BANDED CALCITE, MOUNTAIN PASS MINE, CA

D.S. Montgomery and E.B. Melchiorre. California State University, Department of Geology, San Bernardino, CA, 92407

Geochemical, stable isotope, and field evidence suggest that the Celebration and Friendship Fault Zones have long been deep, active conduits for fluid flow. The upper portion of each fault is wide and porous and serves as a conduit for modern precipitation. Early in the development of the fault zone, the upper reaches were receiving meteoric fluids that probably drained from the east and contained significant Ca, Mg, and HCO_3 from the Goodsprings Dolomite. Later, as erosion changed local drainage patterns and exposed the Mtn. Pass Carbonatite, the vein records influx of meteoric fluids that contain increasing amounts of atmospheric carbon, Ba, and Sr as well as REE's. The concentrations of these elements were quite elevated, as evidenced by their precipitation as unique phases and as substitution within calcite. Early in vein formation, fluids within upper reaches of the fault zone were as warm as 29°C, probably due to oxidation of local sulfides or volcanic activity. Later calcite records low temperatures approximately equal to ambient temperatures. Progressively deeper sections of the faults show thinner and less rhythmic banding, reflecting a fluid source less subjected to seasonal variation and water table fluctuation. Calcite becomes more dominant and Ba, Sr, and REE's decrease in abundance. The early period of elevated groundwater and vadose zone water temperatures would have accelerated the rate of dissolution of these elements at that time. Concentrations of most of these elements in groundwater appear to have decreased over time as they precipitated within the fault veins.

79E. EFFECTS OF ANTHROPOGENIC WATER INPUTS ON ARGENTINE ANT INVASION IN RIPARIAN AREAS OF SOUTHERN ORANGE COUNTY

Kimberly Nelson and Paul Stapp. California State University of Fullerton, Department of Biological Science, Fullerton, CA, 92831

In arid and semi-arid ecosystems of southern California, urban runoff disrupts natural water flows, modifying natural communities downstream. We examined the effects of anthropogenic runoff on the invasion of riparian habitats in southern California by the Argentine ant, *Linepithema humile*. We placed pitfall traps along creeks at Starr Ranch Audubon Sanctuary, Orange County, to describe ant communities at 14 sites along seasonal creeks altered to varying degrees by inputs from the nearby Dove Canyon (DC) housing development. We hypothesized that abundance of Argentine ants would be highest during the rainy "wet" season but would decrease during the "dry" season and with the gradual elimination of anthropogenic water inputs that will result from recent improvements in the DC water control system. Our dry-season surveys in 2007 indicated that sites invaded by Argentine ants generally had a lower diversity of native ants, and lower abundance of other ground-foraging arthropods. Analyses of wet-season sampling in 2007–08 showed a decrease in activity of both Argentine and native ants, as well as reduced species richness of native ants. The overall decrease in ant abundance and diversity probably reflects seasonal changes in aboveground activity. To date, no new sites have been invaded by Argentine ants, and we expect that the elimination of dry-season anthropogenic run-off in summer 2008 will reduce Argentine ant numbers over time. Our study addresses whether eliminating non-natural water sources substantially reduces Argentine ant invasion and aids in the restoration of native ant communities.

80E. BIOLOGICAL DIVERSITY STUDY OF ARTHROPODS OF SELECTED SITES IN THE HAHAMONGHA WATERSHED PARK, PASADENA, CA

Alice Okumura, student participant, Pasadena City College, Pasadena, California

The purpose of this study was to investigate and determine one parameter of the ecological status of the Hahamongha watershed in Pasadena, California, by studying arthropod diversity. We estimated the robustness of the watershed environment and its potential for recovery from regular disturbance to horse use, specially horse manure. Sites were chosen and tested because of the impact horse stable runoff from rainfall could have on arthropod diversity, as opposed to the less disturbed areas of the Coastal Sage Scrub (CSS). Data was collected by setting pit traps for three days between rainfall events. Spring 2008 data collection and analyses supplement initial data found in Fall 2007. Studies found that each site has fauna that are similar in diversity according to Simpson's Index (0.8077 and 0.7919) and Paired 2-sample Student T-test, ($p<0.05$). In general, it appears that the more disturbed areas foster a larger quantity of arthropods than the less disturbed CSS. This discovery suggests that rainfall and disturbance may allow for a greater diversity of arthropods along the waste stream, indicating that in terms of ecosystem stability, food webs may still be intact. This work increases our understanding of the relationship that can exist between recreational use of our natural areas and the conservation of these same areas. This coexistence warrants further study and dialogue.

81E. EFFECTS OF DOUBLE ALGAL BIOFILM FILTRATION ON NITROGEN SATURATED WATER

Mark Ortega. UCLA and Pasadena City College

Currently the issue of water runoff due to agriculture and domestic livestock waste has led the scientific community to focus more attention to the problem of nutrient load management. Both domestically and internationally it has been noted that groundwater is eventually affected, which leads to contamination of an otherwise fresh water source. Nitrogen saturation is the main contaminant in this process. If there was a natural way of cycling this water and reducing or neutralizing the nitrogen, the degree of contamination would decrease allowing for the preservation of a vital fresh water source. There has been substantial evidence proving that algal biofilm has the ability to reduce nitrogen in a fresh water source. An analysis of the effects of a two step algal biofilm filtration might lead to a more efficient way to manage nutrient load. Potentially becoming part of a multi-step filtration process that could effectively reduce contamination.

82E. GENETIC DIVERSITY ANALYSIS OF THE CALIFORNIA INVASIVE CHAMELEON GOBY (*TRIDENTIGER TRIGONOCEPHALUS*); EXPLORATON OF A GENETIC BOTTLENECK WITH COMMENTS ON AN *IN SITU* RISE IN POPULATION

J.R. Radecki and R.R. Wilson. California State University at Long Beach, Department of Biological Sciences, Long Beach, CA, 90840

The chameleon goby, *Tridentiger trigonocephalus*, became prevalent on the California coast from its native Asian population in the 1960s. Recent invasions allow an investigation of potential founder effects, which can be detected by a decline in genetic diversity (bottleneck) in a population out of mutation-drift equilibrium. This study tested the hypothesis that the invasive population of *T. trigonocephalus* in San Francisco Bay California is exhibiting a genetic bottleneck, and has spread by an *in situ* rise in population size as opposed to receiving constant replenishment. Mitochondrial DNA (mtDNA) control region of *T. trigonocephalus* specimens collected from San Francisco Bay were sequenced, and tested for a reduction in genetic diversity. Genetic diversity of *T. trigonocephalus* was compared to a known bottlenecked invasive goby, *Acanthogobius flavimanus*, to determine if a decline in genetic diversity was exhibited by *T.*

trigonocephalus, signifying a founder effect. Examination of 14 samples indicated *T. trigonocephalus* mtDNA is no more variable than *A. flavimanus* with an average sequence divergence of <1% demonstrating a genetic bottleneck. 11 haplotypes with 9 singletons were discovered, suggesting that *T. trigonocephalus* may be receiving on-going immigration in San Francisco Bay. Knowledge of whether this is a self-sustaining invasive population or one from constant replenishment is important when analyzing the impact of a local marine ecosystem invasion.

83E. GENETIC VARIABILITY WITHIN THE SANTA ANA WOOLLY STAR, *ERIASTRUM DENSIFOLIUM* SSP. *SANCTORUM*: REANALYSIS SEVENTEEN YEARS LATER

Y. Sanchez, A. Cohen, and Y. Atallah. California State University, Fullerton, Department of Biological Science, Fullerton CA, 92831

The Santa Ana River Woolly Star, *Eriastrum densifolium* ssp. *sanctorum*, is a federally endangered perennial shrub located in San Bernardino County, CA. Its habitat along the Santa Ana River floodplain has been degraded by development, recreational activities, and the building of the Seven Oaks Dam, rendering geographically isolated metapopulations lacking the seasonal flooding that is evolutionarily important to the development of the plant. In a previous study conducted in 1991, the promising genetic health of the plant was determined using isozyme electrophoresis, which provides measures of heterozygosity, gene flow, genetic assimilation, and therefore the future viability of a species. This project will reanalyze the population genetics of the Woolly Star 17 years later for any changes, using the same methodology as in 1991. Knowledge of genetic variability and any variation from random mating can then be implemented into future management decisions.

84P. SELENIUM STRATIFICATION AND MIXING DYNAMICS OF UPPER NEWPORT BAY, CALIFORNIA

Shelley Shaul, Rachel Andrus, Roxanna Aguirre-Robertson, and Barry Hibbs. Center for Environmental Analysis (CEA-CREST) California State University, Los Angeles, 90032

The Upper Newport Bay Ecological Reserve (UNBER) was founded in 1975 and is one of the few remaining estuaries in Sothern California. The water in the estuary is moderately saline to brackish due to the changes from the twice-daily ebb and flow of the tide and fresh water discharge from San Diego Creek. The estuary is an important habitat to approximately 200 species of birds, including several endangered species. California Department of Fish and Game manages the UNBER and is concerned that the bay may have high concentrations of selenium which has been found to cause adverse health effects in wildlife. Water samples were collected at the top and bottom of the water column at six fixed stations located throughout the bay. Additionally, depth profiles of dissolved oxygen, salinity, pH, and temperature were collected at each of the stations. Mass balance calculations based on conservative anions indicate that both top and bottom waters of the bay are dominated by marine waters with the exception of rain events, which resulted in the water column becoming increasingly stratified. Selenium levels in terrestrial waters averaged 6 ug/L, becoming increasingly dilute with distance from the mouth of San Diego Creek. Marine selenium levels were found to be negligible ($\leq$ 1 ug/L). Nitrate levels average 20 mg/L in terrestrial waters and 2.84 mg/L in marine waters, exhibiting a negative correlation with respect to distance from the mouth of the creek. High selenium levels observed in the upper portion of the bay are of concern due to potential toxicity to wildlife.

85. MICROFLUIDIC IMAGE CYTOMETRY TO DETECT PI3K PATHWAY MARKERS IN BRAIN CANCER

Jane Suh. 700 Westwood Plaza, University of California, Los Angeles, CA

Although a new generation of anticancer drugs targets molecular pathways, cancer treatment still remains inefficient and is in need of further development. Macro-scaled imaging modalities rely on reductions of tumor size to determine the effectiveness of drug treatment. However, this process takes a few months to see noticeable change. Even though patients have similar tumors, they respond differently to treatment because of their unique molecular signature. In order to quickly assess the efficacy of drug treatment and analyze the different molecular profiles, the Microfluidic Image Cytometry was utilized.

The Microfluidic Image Cytometry platform allows for single cell level detection and analysis to compare protein expressions in a cell population's response to drug treatment. Experiments were conducted using the immunocytochemistry method of antibody specific staining. U87 cells, brain cancer cells, were fixated and expression levels were detected inside a PDMS microfluidic chip. Fluorescence dyes were attached to the antibodies to target the PI3K pathway markers in brain cancer: EGFR, EGFRvIII, PTEN, and pS6.

Optimum conditions were determined by measuring fluorescence intensity levels using Metamorph. Optimum antibody concentrations for detection of EGFRvIII, PTEN, and pS6 were established: 0.5 ug/mL, 5 ug/mL, and 4.5 ug/mL respectively. The U87 cells then underwent rapamycin drug treatment for brain cancer and pS6 levels served as readout to measure the effective concentrations, 2 nM to 20 nM, needed in order to inhibit the PI3K pathway.

The Microfluidic Image Cytometry is an effective and quick method for real-time analysis of cancer treatment response. This system will bring cancer treatment to a new age of development because of its small sample volume, large scale analysis, and single cell precision.

86E. A COMPARISON OF EMBOLISM AND EMBOLISM REPAIR IN TWO SALVIA SPECIES

L.M. Velasco and H.J. Schenk. Southern California Ecosystems Research Program, California State University, Fullerton, Department of Biology, 800 N. State College Blvd. Fullerton CA 92831

Salvia mellifera and *Salvia apiana* are two co-occurring shrub species found in coastal sage scrub vegetation in southern California. The Mediterranean climate of this region normally supplies water only during winter and spring, leaving perennial plants to survive the long, hot and dry summer season. Previous research on water relations and the geographical and topographical distribution of the two species suggests that *S. apiana* may be the more drought resistant species. In contrast, the much larger leaf sizes of *S. apiana* and the wood anatomy of the two species, especially the larger-diameter vessels and the absence of vasicentric tracheids of *S. apiana* suggest that it is less drought resistant than *S. mellifera*. The goal of this study was to compare plant water relations during the spring growing season and summer dry season. The following measurements were conducted on co-existing plants of both species: degrees of stem segmentation and hydraulic integration, the amount of embolisms in the plants' hydraulic systems, root vulnerability to embolism formation, specific hydraulic stem conductivities, predawn and mid-day xylem water potentials, and leaf stomatal conductances. Initial results suggests that *S. mellifera* stems and leaves are less-prone to dieback during the dry season and possess more drought adaptations than those of *S. apiana*, which, however, may have a better ability to survive severe summer drought by strongly reducing its canopy to a few basal leaves and stems.

87E. THE LIGHT'S ON BUT NOBODY'S HOME: NEGATIVE PHOTOTACTIC RESPONSE OF *KELLETIA KELLETII* LARVAE TO LIGHT INTENSITY AND WAVELENGTH

K.M. Walker, W.J. Hoese, and D.C. Zacherl. California State University Fullerton, Department of Biological Science, Fullerton, CA, 92834

Many marine invertebrate larvae control their vertical position in the water column, potentially influencing dispersal outcomes. Previous laboratory studies with marine gastropod *Kelletia kelletii* larvae revealed that this species exhibits diel vertical migration (DVM) that is partially controlled by light. We explored light intensity and wavelength as potential cues initiating downward swimming and verified that DVM occurs in the field with plankton tows. We varied full-spectrum light intensity ranging from 99–2.5 PAR (mmol·m-2·s-1) in six replicate 10 cm diameter by 125 cm tall columns each containing 100 one-week old dark-adapted larvae and determined their vertical positions after 2 hrs light exposure. As light intensity decreased, significantly fewer larvae descended (ANOVA, $p<0.0001$). At 2.5 PAR the percent larvae at the top of columns was similar to that in the dark control ($p<0.05$). The effect of wavelength was tested by comparing blue/green light (450–550 nm) at 15 PAR to full spectrum light (380–740 nm) of equivalent intensity. Percent larvae at the surface exposed to blue/green light was not significantly different from larvae exposed to full spectrum light (ANOVA, $p=0.8676$). Surface plankton tows ($n=5$) were conducted at 1200 h and 2400 h off the coast of Palos Verdes, CA to examine whether laboratory findings were consistent with field vertical distributions of larvae. We found that there were significantly more larvae at the surface at 2400 hr versus 1200 hr (T-test, p=0.0008). Findings from this study will help develop mathematical models of larval distributions aimed at estimating dispersal outcomes.

88. PREDICTING LUNG CANCER RELAPSE USING LEVELS OF 2881 PROTEINS

Timothy Wu[1] and Dennis Kibler[2]. [1]stormfyre@sbcglobal.net, University High School, 4771 Campus Drive, Irvine, CA 92612; [2]dennis.kibler@gmail.com, University of California, Irvine, Irvine, CA 92697

A major problem with diagnosing cancer and other gene-related cases is that there is so much data to sift through. Even though scientists have been able to measure each of the approximately 25,000 genes in the human genome, they have no way of identifying patterns associated with gene-caused illnesses because simple identification of single genes is not enough to discover interactions between genes. Even if the searchers were able to specify a range of genes that could possibly contain genes related to the searched-for disease, the potential for combinations between the genes would still generate a large search area. This study attempts to search through a bank of genes to find certain genes that are associated with lung cancer relapse. 2881 genes from 39 patients are analyzed by computer algorithms such as J48, IB1, and NaïveBayes. Two genes were found to be significant. The importance of pattern finding and the significance of the two genes are talked about, as well as the importance of computers in aiding the search for causes of sicknesses related to genes.

89. COMPARISON BETWEEN ALCOHOLIC AND NONALCOHOLIC LIVER USING CT PHANTOM CALIBRATION

Wu, Helena(Hao). Los Angeles Biomedical Research Institute, Harbor UCLA, St. John's Department of Cardiovascular Research

The objective is to engineer a noninvasive methodology for precisely determining the volume, mass, and density of the liver. The secondary goal is to apply this method to obtain accurate measurements of nonalcoholic livers compared to alcoholic livers (patients who consume 1 to 3 drinks per day). Previous techniques for finding organ measurements relied on autopsy and blood tests to detect liver disease.

This study innovates a medical imaging method that focuses on the use of Computed Tomography (CT) and Phantom calibration, which creates a standard for evaluating the fluctuations on the scanner and electric current. Anonymous CT scans with full-body Phantom for 60 non-alcohol consuming patients and 35 alcohol-consuming patients were obtained from the CT scanner database. Image results were analyzed using a software program called Reformat. Histographs and two sample t-tests were created for statistical analysis.

The data revealed that both consistency and accuracy were achieved using the Phantom calibration and the differences in averages between normal and alcoholic measurements were successfully determined. Results indicate that alcoholic livers are larger in volume compared to nonalcoholic livers and the fat content is also higher in the alcoholic group. No significant difference in density was found. In regards to other measurements, alcohol consuming patients demonstrate a higher ratio for liver mass, volume index, and mass index.

It was concluded that Phantom calibration in CT scans produced more accurate results than autopsy or CT alone. This information can be utilized as a guideline to detect abnormalities in volume and volume fat of the liver, which can be the first signs of alcohol related disease such as cirrhosis and fatty liver. The contributions of this project may be utilized in assisting doctors in making treatment decisions for patients with liver disease.

90. TRADITIONAL AGROFORESTRY SYSTEMS IN THE SOCONUSCO REGION OF CHIAPAS, MEXICO

J.L. Gasco. California State University, Dominguez Hills, Dept. of Anthropology, Carson, CA 90747

Across the humid tropics worldwide, indigenous or traditional peoples have adopted a number of similar ecological practices often referred to as "traditional agroforestry systems." Research shows that indigenous populations manage tropical forests and influence the kinds, numbers, and distributions of forest species, creating "forest gardens." They also rely on home or kitchen gardens, the diverse, multistoried gardens adjacent to houses where a wide variety of edible foods, condiments, medicinal plants, and other useful plants are grown. A third element of these agroforestry systems is swidden agriculture, of which an important element is "managed fallows" in which the successional process that follows cultivation is carefully managed to increase the presence of desirable species. In this paper I review what we are learning about traditional agroforestry systems in a region of Mexico that has not previously been a focus of study.

91. LAND MANAGEMENT IN COASTAL CHIAPAS

T. Kasper, J. Lewis, E. Smith, and S. Reimann. California State University, Dominguez Hills, Dept. of Anthropology, Carson, CA 90747

In this paper we describe traditional swidden agricultural practices in the Soconusco region of Chiapas, Mexico. Ethnoecological work done by Dr. Janine Gasco in the community of Barrio Santa Cecelia has shown an intimate relationship between local people and the increasing pressures placed upon their limited resources. Land management has become a critical issue due to an increasing population and shift from traditional milpa farming to short term cattle ranching favored by those seeking quick financial reward. Recent data provided by local residents during field work, that was carried out as part of an Ethnoecology Field Methods course, has projected that this will not be a sustainable way of life in the near future given population increases and scarce availability of usable land. Traditional milpa farming cycles the land between usable and fallow periods allowing the soil to regenerate, creating a sustainable system. Our research shows that traditional swidden techniques fully utilize all available areas within a highly organized community structure. We have now begun to better understand the annual swidden agricultural cycle, and we discuss how this system can be sustainable and productive.

92. *PANELA* PRODUCTION IN MESOAMERICA

S. Ulrich. California State University, Dominguez Hills, Dept. of Anthropology, Carson, CA 90747

The production of *panela* (unrefined sugar) in Mesoamerica is a vital element in traditional rural cultures, and is an economic commodity that involves community cooperation. Panela is a sugar product derived from sugar cane. Despite being an introduced plant from Spain, sugar cane has become a traditional dietary element in Mesoamerica. Contrary to its refined sugar counterpart, panela is unrefined sugar. In this paper I will look at the traditional panela production process in Mexico. The case study presented was observed in a rural town in Chiapas in the winter of 2008 during an ethnobotanical field study class with Anthropologist, Dr. Janine Gasco. I will first present the economic viability of the small-scale production of panela versus the factory produced refined sugar. I will then discuss health consequences for the community comparing the consumption of refined sugar to panela. The main focus of this paper will be on the production process of panela from the cut sugar cane stalk to the marketable end product. The discussion will focus on the use of pre-industrial production techniques that rely mainly on hand-made tools and draft animal produced power. The last aspect of the paper will be on the social implication. Since panela production is a cooperative effort, it relies on communal involvement which is often based on reciprocity, which in turn strengthens social ties.

93. THE PROEYCTO ARQUEOLOGICO TUMBES: AN OVERVIEW TO THE RESEARCH PROJECT

J.D. Moore. California State University, Dominguez Hills, Dept. of Anthropology, Carson, CA 90747

The Department of Tumbes in far northern Peru is one of the archaeologically least-known regions in Andean South America. Beginning in 1996 the Proyecto Arqueológico Tumbes is a multi-phase, binacional project dedicated to basic archaeological research into the region. An initial program of archaeological survey and reconnaissance (1996) led to field inspections of specific sites (2000). In 2003 a limited archaeological testing program was conducted, followed by extensive excavations at four sites in 2006 and 2007. While analysis is still on-going, we now know that the prehistory of Tumbes extends back to at least 4500 BC, that long-distance exchange in obsidian occurred by 1200–800 BC, and that the construction of modest public architecture occurred by 1000–800 BC. Excavations at other, much later archaeological sites has documented the Inka presence in the region and the impacts of the Inka Empire on the Tumbes region. This presentation briefly summarizes the fieldwork and major findings of the Proyecto Arqueológico Tumbes.

94. THE 2007 FIELD SEASON OF PROYECTO ARQUEOLOGICO TUMBES

C. D'Anna and T. Black. California State University, Dominguez Hills, Dept. of Anthropology, Carson, CA 90747

This paper reviews fieldwork conducted for the Proyecto Arqueologico Tumbes, an archaeological field project directed by Jerry Moore (CSU-DH). From mid June to early August 2007, the authors served as research assistants on what was the first comprehensive archaeological study in this region of Peru. The study focuses on the origins of monumental public architecture in northern Peru. Archaeologists use these data to develop theories describing the lifestyle and social organization of the culture at the time of a building's construction. Our role in this research was to supervise excavations at one of the three mounds located at this site, where we were responsible for multiple operational activities. In this paper we will describe these activities in further detail, and conclude with their role in the overall project, as well as explain several of the future objectives on this work.

95. PREHISTORIC DIACHRONIC VARIATION IN MOLLUSCAN ASSEMBLAGES AND PALEOCLIMATIC DISRUPTIONS IN FAR NORTHERN PERU

J.D. Moore and J. Lewis. California State University, Dominguez Hills, Dept. of Anthropology, Carson, CA 90747

Recent (2006 and 2007) archaeological investigations in the Department of Tumbes in far northern Peru have documented significant changes through time in molluscan assemblages from two archaeological sites, El Porvenir and Ulna de Gatos. Dating to the Archaic and Formative periods, materials from the sites range in antiquity from ca. 4700–4500 BC until 1900 BC. Based on the analysis of shellfish species in the assemblages, there were major shifts in the species exploited—in particular a dramatic decrease in Ostrea columbensis. Archaeologists working in adjacent areas of southern Ecuador have noticed similar shifts in the molluscan species and proposed a hypothesis linking these shifts to the effects of El Niño/ Southern Oscillation events in destroying habitats suitable for oyster populations. Sedimentary cores obtained by Moy et al (2002) from Laguna Pallacocha in the southern Ecuadorian highlands provide and alternative source of data on the intensity and frequency in prehistoric ENSO events. The ENSO reconstruction, however, fails to account for the shifts in the molluscan assemblages in the prehistoric sites from Tumbes, suggesting the need to consider alternative explanations of these changes in archaeofaunal assemblages.

96. JOSHUA TREE (*YUCCA BREVIFOLIA*) MORTALITY AND RESPROUTING FOLLOWING THE 2005 HACKBERRY COMPLEX FIRES IN THE MOJAVE DESERT

Philippa M. Drennan and John P. Waggoner, III. Department of Biology, Loyola Marymount University, Los Angeles, CA, 90045

The 2005 Hackberry Complex Fires burned through two of five study sites that were part of a long-term investigation of growth and flowering patterns in *Yucca brevifolia* along an elevational gradient in the Mojave Desert. Individual trees, chosen to reflect the overall size structure of the populations, were tagged

and branch number was recorded annually to approximate growth. Thus mortality due to fire, and post-fire resprouting could be correlated with size and growth rates of individuals. Mortality approximated 93% of trees at the 1450 m site and 100% at the 1545 m site. Trees dead prior to the fire burned completely and were not in evidence after the fire. The few trees that survived at the 1450 m site were shorter than average and showed average growth over the preceding 18 years. By contrast, at a site with unmarked trees chosen for comparison because of lower fire mortality (65%), the trees that survived were 20% taller ($P < 0.05$). Increased tree height and a low stature under-story of grasses by comparison to shrubs apparently reduced the spread of fire to the tree crowns. Fire-induced resprouting occurred for 20 and 25% of the individuals in the 1450 and 1545 m sites, respectively. Only 4% of trees in a comparable unburnt site showed new sprouts. The 18-year growth rates for resprouting trees were almost twice the average at both sites. Sprouting was most abundant on the warmer, south sides of the trunks.

97E. INFLUENCE OF ANTHROPOGENIC NOISE ON SONG STRUCTURE IN *CALYPTE* HUMMINGBIRDS

S. English and A. Houtman. California State University Fullerton, Department of Biological Science, Fullerton, CA, 92831

Urbanization causes an increase in anthropogenic noise, e.g. from traffic and power lines. This increased noise may be a problem in habitats where animals depend on sound transmission for survival and reproduction. Songbirds have been shown to raise the frequency of their song above ambient noise, but it is not known how non-songbirds (non-Passerines) respond to this challenge. Increased anthropogenic noise may decrease the reproductive success of male hummingbirds, as they use song to defend their feeding and breeding territories and to attract potential mates. We recorded songs of male Anna's and Costa's hummingbirds (*Calypte anna* and *Calypte costae*, respectively) during the breeding season in Anza Borrego, CA (San Diego and Imperial Counties) in the summer of 2007. We used spectrogram software to analyze and determine whether they alter song parameters (frequency, amplitude, and duration) in response to increased ambient noise. We also studied possible behavioral changes in the presence of sources of intermittent noise, such as cars. Song analysis suggests that Anna's hummingbird produced shorter and less complex songs in the presence of constant noise, while Costa's hummingbird sang less often in high noise conditions. There was no change in frequency or amplitude of song in high noise conditions. Preliminary data may suggest that *Calypte* hummingbirds rely on visual displays for mate attraction and territory defense because they sing less often. Further analysis of song and behavior, as well as additional song collections, are planned for subsequent breeding seasons.

98E. ARE LOOKS DECEIVING? SHOULD TWO NEARLY IDENTICAL CHITONS REALLY BELONG IN DIFFERENT SUBGENERA?

V.H. Lee[1], A.A. Fore[1], R.Z. El Hajjaoui[1], A. Draeger[2], and D.J. Eernisse[1]. [1]California State University Fullerton, Department of Biological Science, Fullerton, CA 92834; [2]Kensington, California

Two chiton (Mollusca: Polyplacophora) species, *Ischnochiton* (*Ischnochiton*) *boninensis* and *Ischnochiton* (*Haploplax*) *comptus*, live together under the same seashore rocks near Tokyo, Japan. They apparently differ only in whether their girdle scales are ribbed or smooth, respectively. These numerous overlapping scales ornament the girdle surrounding the chiton's eight shell plates like a coat of armor. The scale differences are the sole basis for separating these otherwise indistinguishable species. The extent of similarities implies these might either be very closely related species or perhaps even variation within a single polymorphic species. However, those with smooth scales are currently classified in *Haploplax*, a separate subgenus from those with ribbed scales. The 12 other, mostly Australian, members of *Haploplax* also have smooth girdle scales. We used mitochondrial 16S ribosomal DNA sequence comparison to test whether Japanese chitons with different scale morphology belong to a single species, closely related species, or only distantly related but convergent species. Preliminary DNA comparisons of members of both subgenera from Japan and Australia indicate that chitons with different scale morphology represent sister species that co-occur and together are more distantly related to Australian members of both subgenera. Our evidence implies that the ribs have been lost independently in Australia and Japan, and should not be used as the sole basis for separating members of *Ischnochiton* into different subgenera. Our results also lead to further questions about how these closely related species speciated initially, whether they hybridize, and how they now coexist with such a similar habitat and geographic range.

99E. EVIDENCE FOR 'CONTEXTUAL DECISION HIERARCHIES' IN THE HERMIT CRAB, PAGURUS SAMUELIS

W.L. Billock and S.G. Dunbar. Department of Earth and Biological Sciences, Loma Linda University, Loma Linda, California, USA 92350

Shell and food acquisition behaviors of the hermit crab, *Pagurus samuelis*, were examined in response to cues of shell and food availability. In a preliminary experiment, motivation for acquisition behavior was tested by offering food and shells concurrently. We found that 85.0% of starved hermit crabs ignored tactile cues of shell availability, while 100% of shell-less hermit crabs ignored chemical cues of food availability, demonstrating that current motivation can be the trigger that initiates specific behaviors. When hermit crabs were both starved and shell-less, 77.5% inserted into shells and 17.5% fed. In the two experiments that followed, tactile, visual, and chemical cues were presented in a factorial manner and time was measured between initial contact and either inhabitation of a shell or initiation of feeding. We considered the time difference between initial contact and subsequent behavior to be a measure of hermit crab 'decision time'. In the shell acquisition task, treatments that included tactile cues elicited significantly shorter decision times than treatments without tactile cues. In contrast to the findings of the shell acquisition task, we found that in the food acquisition task, treatments that included chemical cues elicited significantly shorter decision times than those without chemical cues. Even though primary cues elicited the shortest decision time in each of these tasks, in the absence of the primary cue, secondary cues may still be used to make appropriate decisions, albeit with significantly longer decision times. Therefore we propose that hermit crabs sort environmental information in 'Contextual Decision Hierarchies' in order to make accurate and efficient behavioral choices.

100. EFFECTS OF VARIATION IN PREDATOR DENSITY ON GROWTH AND SURVIVAL OF THE TEMPERATE REEF FISH *LYTHRYPNUS DALLI*

J.M. Krug[1], S. Painter[2], and M.A. Steele[1]. [1]California State University, Northridge, Department of Biology, Northridge, CA, 91330; [2]University of California, Los Angeles, Department of Ecology and Evolutionary Biology, Los Angeles, CA, 90024

Predators can play a key role in driving dynamics of prey populations, yet the influence of natural variation in predator density on prey populations of temperate reef fishes is not well known. We used field experiments at 3 sites that varied in predator density to test whether predator density affected the mortality rate, growth rate, or the strength of density-dependence in these rates of the bluebanded goby (*Lythrypnus dalli*) at Santa Catalina Island, CA. The density of populations of adult *L. dalli* was manipulated on small artificial reefs. Densities of one major predator, the kelp bass (*Paralabrax clathratus*), were significantly higher at the site within a marine protected area than at the other two sites; but another predator, the rock wrasse (*Halichoeres semicinctus*), tended to be more abundant at the two non-MPA sites. Survivorship of *L. dalli* was density-dependent at all three sites, but the strength of this density dependence was not related to the density of predators. The density-independent mortality rate was, however, significantly different among sites, although not related to predator density. Growth rates of *L. dalli* were not density-dependent but differed significantly among sites, and there was some evidence that predator density affected the growth of prey. This study suggests that the influences of predator density on the dynamics of temperate reef fish populations are likely to be complex and may be obscured by correlated differences in habitat and interactions among different species of predators.

101. PHYLOGEOGRAPHIC ANALYSIS OF THE FIDDLER CRAB *UCA PRINCEPS* IN THE GULF OF CALIFORNIA AND OUTER COAST OF BAJA CALIFORNIA

M. Kodama, R.A. Ellingson, and D.K. Jacobs. University of California, Los Angeles, Department of Ecology and Evolutionary Biology, Los Angeles, CA, 90095

The fiddler crab *Uca princeps* is widely distributed along the eastern Pacific coast of the Americas, from Southern California to Peru. The previously described *U. monilifera* is now recognized as a subspecies of *U. princeps*, and it is found in the northern Gulf of California where freshwater input from the Colorado River is substantial. We sampled *U. p. princeps* and *U. p. monilifera* along the outer coast of Baja California and the Gulf of California. Although color is not mentioned in formal description of *U. p. monilifera*, crabs obtained from the northern Gulf of California were blue in color, strikingly different from orange individuals of *U. p. princeps* obtained from all other study areas. We conducted phylogeographic analysis using a 657 bp fragment of the mitochondrial cytochrome *c* oxidase subunit I (COI). Despite the high dispersal potential of this species' planktonic larvae, mtDNA sequences displayed exceptionally distinctive genetic structure in the northernmost Gulf of California. However, little phylogeographic structure was found throughout the rest of the Gulf and along the outer coast of Baja California, indicating high levels of gene flow across coastal distances of 1500 km or more. These results are consistent with the subspecies status of *U. p. monilifera*. Further investigation will be conducted using AFLPs or nuclear DNA sequences to examine whether *U. p. monilifera* is a distinct taxon endemic to the northern Gulf.

102P. MOBILITY OF SELENIUM AND NITRATE ALONG A SHALLOW GROUNDWATER FLOWPATH, ORANGE COUNTY, CALIFORNIA

Rachel Andrus, Shelley Shaul, and Barry Hibbs. Center for Environmental Analysis (CEA-CREST) California State University, Los Angeles, 90032 Andre Ellis, Department of Geology, University of Texas- El Paso, TX, 79968

High levels of selenium in the shallow groundwaters of the San Diego Creek watershed coincide with the boundaries of the historic "Swamp of the Frogs," which was drained in the late 19th century. Springs oriented along a shallow groundwater flowpath were sampled for standard inorganic parameters, selenium speciation, Fe, Mn, Mo, and V. Select springs were also analyzed for stable isotopes (δ^{34}S-[SO_4^{2-}], δ^{15}N-[NO_3^-], δ^{18}O-[NO_3^-], and $\delta^{82/76}$Se). These data reveal present-day controls on the mobility of selenium. These waters can be divided into two groups: the relatively more dilute upstream springs (~2500 mg/L TDS) and the more saline downstream springs (~4200 mg/L TDS). Along the "dilute" portion of the flowpath, Fe and Mn are non-detectable; NO_3^- is the dominant form of N (~14 mg/L NO_3^--N, NH_3-N at or below detection limit of 0.01 mg/L); Se increases steadily from 50 µg/L to 228 µg/L where selenate makes up over 98% total dissolved Se; and δ^{34}S-[SO_4^{2-}] becomes isotopically lighter by 1‰. These data are consistent with an oxidizing environment. Along the more saline portion of the flowpath, dissolved Mn increases to 70 mg/L; NO_3^--N concentrations drop to 2.7 mg/L while NH_3-N increase to 0.04 mg/L; Se drops to ~70 µg/L where selenite makes up over 10% of total dissolved Se; and δ^{34}S-[SO_4^{2-}] becomes isotopically lighter by ~3‰ from up-gradient values. These data are consistent with intermediate redox conditions. We expect δ^{15}N-[NO_3^-], δ^{18}O-[NO_3^-], and $\delta^{82/76}$Se to grow isotopically heavier along the "saline" portion of the flowpath. This pattern would be consistent with denitrification and selenium reduction.

103F. GENETIC SEPARATION FOR THE OUTER SOUTHERN CALIFORNIA CHANNEL ISLANDS? MICROSATELLITE DATA FROM KELP BASS (*PARALABRAX CLATHRATUS*)

S.M. Trbovich and R.R. Wilson. California State University-Long Beach, Department of Biological Sciences, Long Beach, CA 90840

Kelp bass (*Paralabrax clathratus*) populations are believed to be genetically homogenous in the eastern Southern California Bight (SCB). However, previous studies suggest that the interface between the California Current to the west and the California Counter-Current to the east differentiates allele frequencies in the eastern and western SCB. To test this hypothesis, adult kelp bass were sampled at San Nicolas (SNI) and Santa Catalina (SCAI) islands and genotyped at three polymorphic microsatellite loci. Preliminary analysis of 35 SNI and 33 SCAI specimens at the AV6 and AV15 loci shows significant (F_{ST}=0.01298, 95% CI: 0.00901) allele frequency differences. Average heterozygosity at SCAI (H_O=0.96154) was higher than SNI (H_O=0.84375), with one locus (AV6) failing to meet Hardy-Weinberg equilibrium in SNI samples. This suggests a discontinuity in genetic connectivity between the eastern and western SCB at its latitudinal center with a reduction in genetic diversity at SNI, indicating less diverse source populations in the western SCB. Future work will expand the sample size, number of loci and analysis methods, collect recruiting juveniles, and add Santa Barbara Island as an intermediate collection site.

104. IDENTIFYING MACHINE LEARNING ALGORITHMS THAT POSSESS HIGH PREDICTIVE ACCURACIES FOR MULTIPLE TYPES OF CANCER

Timothy Wu[1] and Dennis Kibler[2]. [1]stormfyre@sbcglobal.net, University High School, 4771 Campus Drive, Irvine, CA 92612; [2]dennis.kibler@gmail.com, University of California, Irvine, Bren School of Information and Computer Science, Computer Science Department, Irvine, CA 92697

A major problem with predicting and diagnosing cancer and other gene-related cases is that there is so much data to sift through. Even though scientists have been able to measure each of the approximately 25,000 genes in the human genome, they have no way of identifying patterns associated with gene-caused illnesses. Even if the search were narrowed down to a relatively small range of genes, for example 2,881, which *potentially* could contain the genes that cause such an illness, the potential for interactions between the genes would still generate a large search area. This study attempts to find a machine learning algorithm that will work accurately in identifying key genes related with many types of cancer. Many data sets were analyzed using the same algorithms, ZeroR, OneR, J48, IB1, IBk, and NaïveBayes in order to compare the predictive accuracy of each algorithm. Each algorithm differed in the patterns they were designed to find and in the ways that they searched for those patterns. One algorithm was found to be effective in identifying patterns in multiple sets of cancer data, and its results were confirmed by an increase in accuracy of the other algorithms when only the selected genes were analyzed. The importance of computers in gene related disease identification and analysis, as well as the future of medical research, are discussed. Identification of these diagnostic genes by machine learning algorithms provides potential causative genes that would help in the search for a cure to a gene-related disease.

105. PROTEASE INHIBITORS IN AUGMENT TEMOZOLOMIDE-BASED TREATMENT FOR MALIGANT GLIOMAS

J.J. Wang, W.J. Wang, and T.C. Chen. Department of Neurosurgery, University of Southern California, Los Angeles, 90033

The use of HIV protease inhibitors in conjunction with temozolomide (TMZ) based chemotherapy for patients with malignant gliomas has never been attempted before. Protease inhibitors, which were approved by FDA on May 1999,[i] are orally administered, and are generally very safe and well tolerated by patients. Protease inhibitors have been previously demonstrated to have anti-tumor, anti-angiogenesis, and anti-invasive properties in Kaposi's sarcoma. In addition, recent data have indicated that the protease inhibitors have radio-sensitizing and chemo-sensitization properties as well. First of all, in this experiment, we propose to demonstrate via *in-vitro* models (glioma cell lines and cell cultures) that protease inhibitors may have a synergistic effect in inducing cytotoxicity during combination treatment with temozolomide-based chemotherapy. The best type of protease inhibitor and the ideal dosage will also be determined *in-vitro*. Second, we will apply the same conditions to an *in-vivo* nude mice subcutaneous and intracranial glioma model. If the hypotheses and goals of this research are realized, adding a protease inhibitor to the default temozolomide-based chemotherapy may be done more easily and safely, something that will hopefully reduce the malignant gliomas from a fatal disease to a less severe chronic illness. ***VB Pai and MC Nahata Nelfinavir mesylate: a protease inhibitor The Annals of Pharmacotherapy: Vol. 33, No. 3, pp. 325–339.***

106. REGULATION OF *ALDEHYDE OXIDASE 4 (AOX4)* GENE BY THE GRAINYHEAD-LIKE EPITHELIAL TRANSACTIVATOR (GET1) TRANSCRIPTION FACTOR

A. Venkatesh, A. Bhandari, and B. Andersen. Departments of Medicine and Biological Chemistry, University of California, Irvine, CA, 92697

Skin acts as a barrier preventing toxic substances from entering and disrupting internal homeostasis. There are several skin disorders and hereditary diseases associated with a defective skin barrier. Previous work done in the Andersen laboratory has shown that Get1, a transcriptional factor, regulates the terminal differentiation program in the epidermis. *Get1*-deleted mice die prenatally due to neural tube closure defects and exhibit defective terminal differentiation of the epidermis. Expression analysis of backskin RNA from wild type and *Get1*-deleted mice at different stages of embryonic development as well as from different epithelia, identified the Aldehyde oxidase 4 *(Aox4)* gene as one of the most significantly downregulated in the *Get1*-deleted mice. Members of the Aldehyde oxidase gene family have shown to be important in the retinoic acid pathway which plays an important role in the differentiation of keratinocytes. To investigate whether Get1 directly regulates *Aox4*, 1 kb and 2 kb regions upstream of the transcription start site were cloned into the pGL3 luciferase reporter vector. Measurements of the luciferase activity of these recombinant vectors in response to Get1 can assist in evaluating whether Get1 directly binds to the promoter region. This work paves the way to further test the hypothesis that *Aox4* is directly regulated by Get1.

107. CARBOHYDRATE-BASED EXPERIMENTAL THERAPEUTICS FOR CANCER, HIV/AIDS AND OTHER DISEASES

Sarine Shahmirian and Steven B. Oppenheimer. California State University Northridge, Department of Biology and Center for Cancer and Developmental Biology, Northridge, CA, 91330

Science has recently seen a fascinating, new area of research: carbohydrate-based experimental therapeutics for cancer, HIV/AIDS, and other diseases. A model system of washed yeast (*Saccharomyces cerevisiae*) that possessed mannose-rich cell surfaces and washed concanavalin A (Con A) derivatized agarose beads that preferentially bind to glycans containing mannose/glucose residues was used. This is a model system that can be used, for example, in the development of drugs that may prevent AIDS infection. This is the case because the AIDS virus, HIV, like yeast, has cell surface mannose residues, and human cells to which HIV binds have receptors for mannose, like the Con A beads. Using the system, different concentrations of two sugars, alpha methyl mannose and D-melezitose, were tested over a 30 minute time course, assaying how much yeast remained bound to the beads at 10 minute intervals with and without sugar at each sugar concentration tested. The highest sugar concentration (25 mM) tested was most effective in causing dissociation of the yeast from the beads and the 50/50 mixture of the 2 sugars was less effective than the single sugars in causing dissociation at the lower concentrations (less than 25 mM). The results suggest that careful attention should be paid to sugar concentration and incubation times in experiments using lectin derivatized beads in molecular purification protocols and in the development of carbohydrate-based drugs and diagnostic tests. In the second and third experiments of the project, which were preliminary experiments aimed at perfecting the yeast and Con A bead model system, conditions for the storage of the Con A beads were tested and, like sugars, salts at various concentrations were tested for their ability to cause dissociation of yeast from the Con A beads.

108. TO SPECIATE OR NOT TO SPECIATE?: POPULATION STRUCTURE OF *HAMINOEA VESICULA* (OPISTHOBRANCHIA: HAMINOEIDAE) IN THE NORTHEAST PACIFIC

Bonnie R. Lei. Walnut High School, 400 North Pierre Road, Walnut, CA 91789. Department of Biological Sciences, California State Polytechnic University, Pomona, 3801 West Temple Avenue, Pomona, CA 91768-4032

Two separate populations of *Haminoea vesicula* (Gould, 1855) are assessed based on complete specimens and shells collected primarily in British Columbia, Canada and Southern California, United States with the purpose of determining whether a speciation event for this species is justified.

Specimens are compared using morphological and genetic characteristics. Evaluation of diagnostically reliable features including the external morphology, radulae, and gizzard plates through SEM photomicrographs, camera lucida, and digital photography revealed consistent differences that support a divergence between the two populations which may culminate in speciation. The shell morphology and male couplatory organs present no variations. Mitochondrial genetic markers (partial 16S fragments) offer

promising additional data to test morphological differences. Protocols for DNA extraction and sequencing of long-term preserved tissue are used to compare the two populations.

With the presented data it is clear that the two populations show steady variation typical for a process of divergence. However, further investigation and corroboration of differences is needed before sufficient evidence is compiled to support the establishment of a new name for the northern population. Determination of the population structure of *H. vesicula* or the possibility of the existence of a second, cryptic species in the northern part of the range is of the utmost importance in further understanding the biology of this species. This knowledge will contribute to understanding the influence of environmental change on this species through factors such as global warming.

109. SURVEY OF THE PLEISTOCENE *CAMELIDAE* MATERIAL OF RALPH B. CLARK REGIONAL PARK INTERPRETIVE CENTER, ORANGE COUNTY, CA

M.K. Crowe and L. Babilonia. Ralph B. Clark Regional Park, Interpretive Center, 8800 Rosecrans Ave. Buena Park, CA 90621

A faunal list of the Pleistocene camel species at R.B. Clark Regional Park Interpretive Center (RCIC) was recorded. The Clark Park specimens were compared with other specimens in order to verify and clarify previous identifications. A total of 23 specimens were analyzed and were identified to approximate identifications. Three specimens were identified as part of the camel family or *Camelidae*. Seven were identified as *Camelops*, and eleven were identified as *Camelops hesternus*. One specimen was identified as *Hemiauchenia* and one was removed from the camel specimens. The material at RCIC is fairly diversified. The *Camelops hesternus* specimens of RCIC were compared with those of *Camelops hesternus* in the La Brea tar pit collection, since La Brea has mostly *Camelops hesternus*. The specimens were then photographed to provide further information about the morphological similarities.

110. SEE 89

111. EVOLUTIONARY CHANGES IN THE DIGESTIVE TRACT OF THE PARASITIC CATFISHES (TRICHOMYCTERIDAE)

Jonathan N. Baskin[1], **Brian Diep**[2], Jason Hwan[1], and Diana Jeon[1]. [1]California State Polytechnic University Pomona, Department of Biological Sciences, Pomona, CA, 91768; [2]San Gabriel High School, San Gabriel, CA, 91776

Many species of the widespread Neotropical catfish family Trichomycteridae are known for their parasitic habits of feeding on blood, scales and mucus of other fishes, while other species of the family are more generalized predators on insects. One species of the parasitic group, *Pareiodon microps*, has reverted back to a predatory habit of feeding on fish flesh. The entire parasitic species group has a straight gut, losing the stomach and looping structure found in other species. These were found also to have reduced intestinal walls and villi. *P. microps* is found to have redeveloped a strong intestinal wall, as well as intestinal villi, and developed an enlarged rectum. The internal structure of the *P. microps* gut is more complex compared to other members of the family.

112. MODELING THE TOXIC EFFECTS OF SILVER NANOPARTICLES UNDER VARYING ENVIRONMENTAL CONDITIONS

Joyce Chai. Palos Verdes Peninsula High School, Rolling Hills Estates, CA. Mentor: Professor Eric M.V. Hoek, UCLA Department of Civil and Environmental EngineeringTeacher: Peter Starodub, Palos Verdes Peninsula High School

Although 25 percent of the nanotechnology consumer market contains silver nanoparticles, the obscurity of these associated environmental risks necessitates the development of a reproducible assay to

quantify the toxicity of nanosilver. Phase I of this investigation conducted preliminary experiments in order to determine the optimum conditions for the bacterial toxicity assay. In Phase II, the development of a high throughput method quantified the toxicity, redefined as the percentage of cells that died in excess to its natural death, based on ratios of the fluorescence of live to dead cells. This novel technique established a positive logarithmic association between the various concentrations of nanosilver and its resultant toxicity on model environmental bacteria, Pseudomonas putida and Bacillus subtilis; as concentration increases, toxicity increases at a logarithmic rate. In Phase III, a practical application of a silver nanoparticle water filtration system revealed the passage of nanosilver through a 1-micron filter into the filtered waters. This may, in turn, come into indirect or direct contact of the environment and continue to induce toxic effects in the environmental surroundings. This investigation not only showed that a nanosilver concentration as low as 1-micromolar can induce approximately 50% death of surrogate environmental bacteria, but it also revealed the potential risks of consumer products that contain silver nanoparticles. This investigation took steps toward understanding and quantifying the potential environmental consequences of nanotechnology.

113. CHEMOTHERAPY AND THE UNFOLDED PROTEIN RESPONSE

Kevin Pan (Lynbrook High School), Dr. Albert C. Koong, PhD. and Mike Olson, M.D. Department of Radiation Oncology, Stanford University

The unfolded protein response (UPR) is an essential cellular survival tool that counteracts the detrimental effects of outside stresses such as hypoxia and nutrient deprivation by allowing the proper folding of polypeptides within the endoplasmic reticulum. The UPR has been shown to be involved both in carcinogenesis and in the response of cancer cells to chemotherapy, yet little is known regarding the specific effects of chemotherapy on the UPR. We sought to investigate the relationship between the UPR and certain chemotherapeutic drugs, mainly Paclitaxal (Taxol®), a drug commonly used in the treatment of breast and ovarian cancers, and Gemcitabine (Gemzaar®), a drug used widely in the treatment of pancreatic cancer. We utilized HT1080 fibrosarcoma cells that were stably transfected with luciferase reporters of different arms of the UPR and exposed each cell line to both Paclitaxal and Gemcitabine. Our results indicate that Paclitaxal but not Gemcitabine specifically activates the IRE1 arm of the UPR. A second, parallel arm of the UPR which is regulated by the activation of the ATF4 protein was not stimulated by Paclitaxal. Interestingly, a survival assay showed that Paclitaxal did little to kill HT1080 fibrosarcoma cells in culture, whereas Gemcitabine was toxic. The activation of the UPR by Paclitaxal may explain in part the ability of HT1080 cells to survive exposure which would otherwise be lethal, and suggests that inhibitors of the UPR, currently under development, may provide a means to increase efficacy of certain chemotherapies.

114. THE ROLE OF THE GET1 TRANSACTIVATOR IN THE REGULATION OF EPITHELIAL BARRIER STRUCTURE AND FUNCTION IN BLADDER EPITHELIUM

T. Kwong, A. Soto, and B. Andersen. Chao Cancer Laboratory, University of California Irvine, Department of Medicine, Irvine, CA, 92697

The Grainyhead-like epithelial transactivator (Get1) is a transcriptional regulator linked to epithelial differentiation in the bladder. Uroplakin 2 is an essential bladder structure protein found to be lacking in Get1 knockout mice. The purpose of this experiment was to investigate the particular interaction between Get1 and Uroplakin 2 (Upk2). A prospective Get1 binding site was identified upstream of the Upk2 gene, ligated into a pGL3 luciferase assay expression vector, and transfected into a human keratinocyte cell line. Luciferase assay results indicated that the tested binding site did show up regulation in the presence of Get1, supporting the hypothesis that the tested Get1 binding site was the actual connection between the presence of Get1 and Upk2.

115. THE EL SEGUNDO BLUE BUTTERFLY RETURNS TO SOUTH BAY BEACHES

A. Dalkey[1] and M. Acosta[2]. [1]Palos Verdes Peninsula Land Conservancy, 916 Silver Spur Road #207, Rolling Hills Estates, CA 90274; [2]SEA Lab, 1021 North Harbor Drive, Redondo Beach, CA. 90277

In a case of "if you plant it, they will come", the endangered El Segundo blue butterfly (*Euphilotes battoides allyni*) quickly exploited new habitat at beach bluffs in the south bay portion of Santa Monica Bay. Historically large populations of this butterfly inhabited its namesake El Segundo dunes until the habitat was largely built over, particularly during the post-World War II boom. The butterfly was listed as endangered in 1976, with limited populations in existence, largely cut-off from each other. Then, in 2001, the Beach Bluffs Restoration Project was formed, an ad hoc committee comprised of various citizens, governmental agencies, and non-profit organizations having the common goal of restoring native dune and bluff habitat along the south bay beaches. Although the planned habitat could support the El Segundo blue butterfly, plans were solely focused on restoring native habitat with butterfly reintroduction plans set on the back burner. Starting as a demonstration project in Redondo Beach, the effort utilized a multi-component approach that included educational, volunteerism, work experience, and infrastructure improvement programs. The SEA Lab, a Los Angeles Conservation Corps program, spearheaded the on-site effort, improving their restoration abilities and expanding to Dockweiler and Manhattan Beaches. All the while, reintroduction of the butterfly was left for sometime in the future. However, nature had her own educational component in store. By travelling much further than previously thought possible, we learned the El Segundo blue butterfly had occupied new habitat at the Redondo Beach and Dockweiler Beach sites in June 2007.

116. EFFECTS OF VARYING ZINC CONCENTRATIONS ON BIOLUMINESCENCE IN *CYPRIDINA HILGENDORFII*

Debra Chang. Rancho Palos Verdes Peninsula H.S.

This study determined the effect of varying zinc concentration on the bioluminescence of *Cypridina hilgendorfii*, a marine shrimp. The results were compared to my previous year's project that determined the effect of phosphate on this crustacean. The result of the present experiment may be used to find the concentration of a common water pollutant, the metal zinc.

Preserved *Cypridina* were introduced into zinc sulfate solutions in concentrations of 0.05 g/100 mL, 0.1 g/100 mL and 0.15 g/100 mL. The Control Group solution was undosed distilled water. 0.05 g of ground *Cypridina* and 2 mL of zinc solution were placed in a cuvette. Four trials were done per concentration. Digital photographs were taken in a darkroom, exposing the film at 10, 15 and 20 seconds.

The results were quantified using AnalySIS software. The program calculated the percentage of the picture that was black. This percentage was subtracted from 100% to determine the percentage of the rest of the picture, which was light in the white-to-blue spectrum. This light frequency was determined for each picture.

With increased concentrations of zinc sulfate, the light frequency also increased. These results contrasted with the results from the previous year's study, where sodium phosphate caused a diminishment of light. Future research can be done to discover why zinc enhanced the bioluminescent reaction while phosphate hindered it. Several possible explanations are presented. With the significant effect on the amount of light being emitted, it is apparent that *Cypridina* can be used as a bioluminescent indicator for water quality.

117. THE ECOLOGY OF COYOTES ON THE PALOS VERDES PENINSULA

Rebecca Niemiec[1]. Chadwick High School, 26800 South Academy Drive, Palos Verdes, CA 90274; Ann Dalkey, Palos Verdes Peninsula Land Conservancy, 916 Silver Spur Road #207, Rolling Hills Estate, CA 90274. Dr. Paul Stapp, Department of Biological Science, California State University, Fullerton PO Box 6850, Fullerton, CA 92834

Coyotes were believed to have re-colonized the Palos Verdes Peninsula in the mid-1990's. Their presence has generated controversy as local residents have called for coyotes' removal on the claim that coyotes have preyed upon their cats. However, no one has documented where the coyotes are, their abundance on the Peninsula, or how their activity is affected by environmental factors. We report results of a two-year field study to identify the areas of the Peninsula inhabited by coyotes, determine key aspects of their diet, and document the effect of the lunar cycle on their activity. We used public sightings to identify canyons used by coyotes, then collected scat and monitored gypsum track stations to verify their presence. Scats were examined to identify evidence of cat remains. We also monitored tracks in one canyon intensively over a 3-month period to examine the effects of moonlight on coyote activity. This intensive study included a motion sensor game camera and a shorter supplementary study in another canyon previously determined to be frequented by coyotes. We found evidence of coyotes in many areas of the Peninsula and determined that they do prey on cats as well as native prey and berries. Coyote activity did not appear to be affected by moonlight. We also found that mesopredators such as foxes and raccoons were scarce during periods of coyote activity. We hope that information from this project will be used to help find solutions to the controversy over coyotes in Palos Verdes.

118. GENETIC COMPONENT IN MINIATURE SIZE MUTATION OF THE ENDANGERED PALOS VERDES BLUE BUTTERFLY

E. Yang[1] and J. Johnson[2]. [1]Palos Verdes Peninsula High School, 27118 Silver Spur Road, Rolling Hills Estates, CA 90274; [2]The Urban Wildlands Group, Los Angeles, CA 90024-0020

The endangered Palos Verdes blue butterfly (*Glaucopsychae lgydamus palosverdesensis*) is twice the size of the silvery blue butterfly (*G. lygdamus*). The Palos Verdes blue butterfly (PVB), which is reared in captivity, faces a genetic bottleneck that may increase the chances it becoming miniaturized. Avoiding this bottleneck is critical for insuring against the extinction of lycaenid *Glaucopsyche lygdamus palosverdesensis* (Palos Verdes blue butterfly). Captive PVBs with body sizes less than or equal to half the size of a regular adult butterfly were identified as "tiny". The tiny butterflies are approximately the same size as the silvery blue butterfly. Tiny and normal-sized butterflies were placed separately in multiple plant boxes, where mating and ovipositioning occured. The rate of tiny butterflies was determined for 48 different genelines. The tiny population was not distributed normally and was tested by the non-parametric Mann-Whitney Rank Sum to determine the presence of tiny clustering within the population. Overall, four gene lines showed a propensity to harbor a higher rate for the expression of the tiny characteristic. Researchers will monitor mating of the butterflies belonging to gene lines with the tiny characteristic to insure the health of the captive PVB population. Future studies will examine the relationship between the matriarch's age at the time of ovipositioning, the average weight of the resulting pupae, success levels of different types of food, and possible substitute light sources to the expression of the tiny characteristic.

119. STUDY ON THE TRUNCATION OF CONVEX SYMMETRICAL POLYHEDRA

Brian Li. Chadwick School

Truncations of convex symmetrical polyhedra were investigated. Truncation planes were created at each vertex such that the plane was perpendicular to the line from the center of the polyhedron to the vertex. These planes were pushed into the polyhedron with respect to a parameter and truncated the polyhedron. A computer algebra routine was created in order to automate this process and produce a new polyhedron with simply input of an original polyhedron and the parameter of truncation. Three types of truncation were encountered with respect to the depth of the cut. The first, a shallow truncation, was a truncation in which the truncations planes only interacted with the original polyhedron and not each other. This type of truncation related to a parameter value such that the cut was very shallow. A deep truncation occurred when the truncation planes began to interact with each other as well as with the old polyhedron. The final truncation, a dual truncation, occurred when only the truncation planes were interacting with each other to produce the new polyhedron. This point became a point of stability because any parameter value that cut further into the polyhedron would only scale the outcome of the dual truncation, which is the polyhedron's dual.

120. ACHIEVING NUTRIENT REDUCTIONS IN THE NEWPORT BAY WATERSHED – A CASE HISTORY

C.P. Crompton and K.H. Cowan. County of Orange, OC Watersheds Program, Anaheim, CA, 92806

Since 1998, the County of Orange has been implementing and managing a Nutrient TMDL for the Newport Bay watershed. This TMDL was developed due to large algal blooms that were common in Newport Bay during the 1980's and early 1990's. Excessive nitrogen loading to Newport Bay was determined to be the most likely cause of the algal blooms. Key point and non-point sources have been identified. BMPs have been implemented for major point source discharges and a regional BMP has been implemented to mitigate urban runoff. Over the past several years, monitoring data have shown that total inorganic nitrogen concentrations and total nitrogen loads to Newport Bay have been steadily decreasing. In addition, algal biomass in Newport Bay has also significantly been reduced and the green algae species *Ulva* (indicative of nutrient pollution) has been mostly replaced by *Ceramium*, a non-nuisance brown algae.

The remaining challenge for the watershed is to develop management strategies for the impact of nitrogen laden groundwater that passively seeps into the surface waters. During very wet years, such as 2005, groundwater can have a major impact on algal blooms in the bay. This non-point source is being addressed through a large stakeholder group, the Nitrogen and Selenium Management Program (NSMP). The NSMP is looking at the sources, loads, and treatment options for nitrogen on a watershed scale. The ultimate goal of the program is to develop management strategies that will attain nitrogen related water quality standards and protect the beneficial uses of Newport Bay.

INSTRUCTIONS FOR AUTHORS

The BULLETIN is published three times each year (April, August, and December) and includes articles in English in any field of science with **an emphasis on the southern California area**. Manuscripts submitted for publication should contain results of original research, embrace sound principles of scientific investigation, and present data in a clear and concise manner. The current AIBS *Style Manual for Biological Journals* is recommended as a guide for contributors. Consult also recent issues of the BULLETIN.

MANUSCRIPT PREPARATION

The author should submit at least two additional copies with the original, on 8½ × 11 opaque, nonerasable paper, double spacing the entire manuscript. Do not break words at right-hand margin anywhere in the manuscript. Footnotes should be avoided. **Manuscripts which do not conform to the style of the BULLETIN will be returned to the author.**

An abstract summarizing in concise terms the methods, findings, and implications discussed in the paper *must* accompany a *feature article. Abstract should not exceed 100 words.*

A feature article comprises approximately five to thirty typewritten pages. Papers should usually be divided into the following sections: abstract, introduction, methods, results, discussion and conclusions, acknowledgments, literature cited, tables, figure legend page, and figures. Avoid using more than two levels of subheadings.

A research note is usually one to six typewritten pages and rarely utilizes subheadings. Consult a recent issue of the BULLETIN for the format of *notes*. Abstracts are not used for notes.

Abbreviations: Use of abbreviations and symbols can be determined by inspection of a recent issue of the BULLETIN. **Omit periods after standard abbreviations:** 1.2 mm, 2 km, 30 cm, but Figs. 1–2. Use numerals *before* units of measurements: 5 ml, but nine spines (10 or numbers above, such as 13 spines). The metric system of weights and measurements should be used wherever possible.

Taxonomic procedures: Authors are advised to adhere to the taxonomic procedures as outlined in the International Code of Botanical Nomenclature (Lawjouw et al. 1956), the International Code of Nomenclature of Bacteria and Viruses (Buchanan et al. 1958), and the International Code of Zoological Nomenclature (Ride et al. 1985). Special attention should be given to the description of new taxa, designation of holotype, etc. Reference to new taxa in titles and abstracts should be avoided.

The literature cited: Entries for books and articles should take these forms.

McWilliams, K. L. 1970. Insect mimicry. Academic Press, vii+326 pp.

Holmes, T. Jr., and S. Speak.1971.Reproductive biology of Myotis lucifugus. J. Mamm., 54:452–458.

Brattstrom, B. H.1969.The Condor in California. Pp. 369–382 in Vertebrates of California. (S. E. Payne, ed.), Univ. California Press, xii+635 pp.

Tables should not repeat data in figures *(line drawings, graphs, or black and white photographs) or contained in the text.* The author must provide numbers and short legends for tables and figures and place reference to each of them in the text. Each table with legend must be on a separate sheet of paper. All figure legends should be placed together on a separate sheet. **Illustrations and lettering thereon should be of sufficient size and clarity to permit reduction to standard page size;** *ordinarily they* **should not exceed 8½ by 11 inches** in size and after final reduction lettering must equal or exceed the size of the typeset. All half-tone illustrations will have light screen (grey) backgrounds. Special handling such as dropout half-tones, special screens, etc., must be requested by and will be charged to authors. **As changes may be required after review, the authors should retain the original figures in their files until acceptance of the manuscript for publication.**

Assemble the manuscript as follows: cover page (with title, authors' names and addresses), abstract, introduction, methods, results, discussion, acknowledgements, literature cited, appendices, tables, figure legends, and figures.

A cover illustration pertaining to an article in the issue or one of general scientific interest will be printed on the cover of each issue. Such illustrations along with a brief caption should be sent to the Editor for review.

PROCEDURE

All manuscripts should be submitted to the Editor, Daniel A. Guthrie, W. M. Keck Science Center, 925 North Mills Avenue, Claremont, CA 91711. Manuscripts may be submitted by mail, or by e-mail to dguthrie@jsd.claremont.edu as a Word document. **Authors are requested to submit the names, addresses and specialities of three persons who are capable of reviewing the manuscript. Evaluation of a paper** submitted to the BULLETIN begins with a critical reading by the Editor; several referees also check the paper for scientific content, originality, and clarity of presentation. Judgments as to the acceptability of the paper and suggestions for enhancing it are sent to the author at which time he or she may be requested to rework portions of the paper considering these recommendations. The paper then is resubmitted on disk in word format and may be re-evaluated before final acceptance.

Proof: The galley proof and manuscript, as well as reprint order blanks, will be sent to the author. He or she should **promptly** and **carefully read** the proof sheets for errors and omissions in text, tables, illustrations, legends, and bibliographical references. He or she marks corrections on the galley (copy editing and proof procedures in *Style Manual*) and **promptly returns both galley and manuscript** to the Editor. Manuscripts and original illustrations will not be returned unless requested at this time. **All changes in galley proof attributable to the author (misspellings, inconsistent abbreviations, deviations from style, etc.) will be charged to the author. Reprint orders are placed with the printer, not the *Editor*.**

CONTENTS

A Fossil Skull of the Extant Blue Marlin (*Makaira nigricans* Lacepède, 1802) from the Late Miocene of Orange County, California. Harry L. Fierstine 45

An Initial Carnivore Survey of Griffith Park, Los Angeles, California. Paul D. Mathewson, Stephanie N. Spehar, and Daniel S. Cooper 57

A New Early Miocene Species of *Pogonias* (Teleostei: Sciaenidae) Based on Otoliths from California. Gary T. Takeuchi and Richard W. Huddleston 68

Annual Meeting of Southern California Academy of Sciences 81

Future Meetings 82

Acknowlegements 82

Student Award Winners 83

Alphabetical list of Presenters at 2008 Annual Meeting 84

Schedule of Program for 2008 Annual Meeting 85

Abstracts, in program order 99

Cover: Skull of *Makaira nigricans* (OCPC 31001), Capistrano Formation, late Miocene, Orange County, California. See text for details.

Serials
QH
1
.S69
v.107
no.3
24116-140

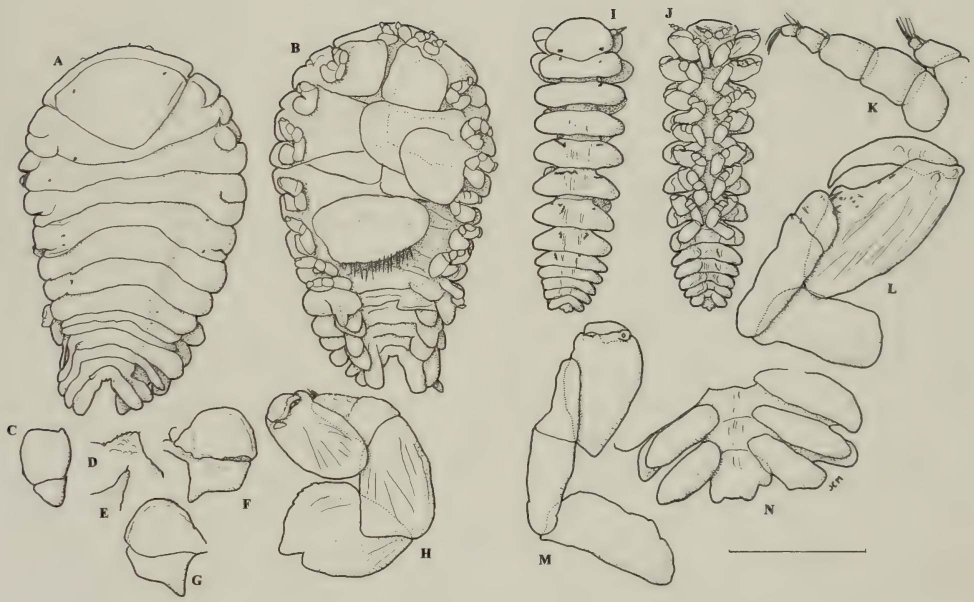
ISSN 0038-3872

SOUTHERN CALIFORNIA ACADEMY OF SCIENCES

BULLETIN

Volume 107

Number 3



BCAS-A107(3) 145–188 (2008)

December 2008

Southern California Academy of Sciences

Founded 6 November 1891, incorporated 17 May 1907

OFFICERS

Brad Blood, *President*
Judith Lemus, *Vice-President*
John Roberts, *Secretary*
Daniel A. Guthrie, *Treasurer*
Daniel A. Guthrie, *Editor*
Ralph G. Appy, *Past President*
Robert Grove, *Past President*
Daniel J. Pondella, II, *Past President*
John H. Dorsey, *Past President*

BOARD OF DIRECTORS

2005–2008	2006–2009	2007–2009
Jonathan N. Baskin	M. James Allen	Brad R. Blood
John Roberts	Sabrina Drill	Julianne Kalman
Gloria J. Takahashi	Gordon Hendler	Jerry Schubel
Andrea Murray	Darren Sandquist	Ann Dalkey
Phillippa Drennan	SusanYoder	Edith Reed

Membership is open to scholars in the fields of natural and social sciences, and to any person interested in the advancement of science. Dues for membership, changes of address, and requests for missing numbers lost in shipment should be addressed to: Southern California Academy of Sciences, the Natural History Museum of Los Angeles County, Exposition Park, Los Angeles, California 90007-4000.

Professional Members	$45.00
Student Members	25.00

Memberships in other categories are available on request.

Fellows: Elected by the Board of Directors for meritorious services.

The Bulletin is published three times each year by the Academy. Manuscripts for publication should be sent to the appropriate editor as explained in "Instructions for Authors" on the inside back cover of each number. All other communications should be addressed to the Southern California Academy of Sciences in care of the Natural History Museum of Los Angeles County, Exposition Park, Los Angeles, California 90007-4000.

Date of this issue 12 December 2008

♾ This paper meets the requirements of ANSI/NISO Z39.48-1992 (Permanence of Paper).

CALIFORNIA
ACADEMY OF SCIENCES
DEC 3 0 2008
LIBRARY

Annual Meeting of the Southern California Academy of Sciences

Marymount College, May 29–30, 2009

FIRST CALL FOR SYMPOSIA AND PAPERS

The Southern California Academy of Sciences will hold its annual Meeting for 2009 on the campus of Marymount College, Palos Verdes Friday and Saturday May 29–30.

Presently the following symposia are in the planning stages. If you would like to organize a Symposia for this meeting, or have suggestions for a symposia topic, please contact An Dalkey adalkey@pvplc.org or John Roberts at jroberts@csudh.edu. Organizers should have a list of participants and a plan for reaching the targeted audience.

Note: Abstracts will be due on April 17, 2009. Check our web page for further information (http://scas.jsd.claremont.edu/)

Proposed Symposia for 2009

Reef Biology: Bob Grove (grovers@sce.com) and Dan Pondella (pondella@oxy.edu)

Coastal Sage Scrub Ecology: Darren Sandquist (dsandquist@fullerton.edu)

Runoff and Pollution Control: John Dorsey (jdorsey@lmu.edu)

Southern California Archaeology: Andrea Murray (apmurray@pasadena.edu)

Southern California Paleontology:

Environmental Issues on the Palos Verdes Peninsula

Contributed papers: Sessions of Contributed Papers will occur both days.

Contributed Papers and Posters: Both professionals and students are welcome to submit abstracts for a paper or poster in any area of science. Abstracts are required for all papers, as well as posters, and must be submitted in the format listed on the society webpage. Maximum poster size is 32 × 40 inches.

In addition **Junior Academy members** will submit papers for Saturday sessions.

Abstracts of presented papers and posters will be published as a supplement to the August 2009 issue of the Bulletin.

Student Awards: Students who elect to participate are eligible for best paper or poster awards in the following categories: ecology and evolution, molecular biology,genetics and physiology, and physical sciences. In addition the American Institute of Fishery Research Biologists will award best paper and poster in fisheries biology. A paper by any combination of student and professional co-authors will be considered eligible provided that it represents work done principally by student(s). In the case of an award to a co-authored paper, the monetary award and a one year student membership to the Academy will be made to the first author only.

Bull. Southern California Acad. Sci.
107(3), 2008, pp. 145–157

New Records of Pseudionine Bopyrid Isopods, including two new Species and one new Genus, infesting Porcellanid Crabs (Decapoda: Anomura) on the Pacific coast of North and Central America

John C. Markham

Arch Cape Marine Laboratory, Arch Cape, Oregon 97102-0133, USA
jmarkham@seasurf.com

Abstract.—*Aporobopyrus bourdonis*, new species, earlier reported from the Pacific coast of Mexico but never described, infests *Petrolisthes edwardsii* (de Saussure), the same host species as before, in Costa Rica. *Aporobopyrus muguensis* Shiino, 1964, previously reported several times along the coast of California infesting *Pachycheles rudis* Stimpson and *P. pubescens* Holmes, is redescribed on the basis of material from Monterey, California, infesting *P. pubescens*. *Aporobopyrus trilobatus* (Nierstrasz and Brender à Brandis, 1925), previously known from the Caribbean Sea and the Pacific coast of Mexico, infests *Petrolisthes ortmanni* Nobili, a new host record, in Costa Rica. *Discomorphus magnifoliatus*, new genus, new species, infests *Petrolisthes cinctipes* (Randall) in central California. Synonymies are given for all species. Included is a summary of all porcellanids known to bear bopyrid parasites in the eastern Pacific.

There are relatively few species of bopyrid isopods known from the Pacific coast of the Americas (Markham 1992). Ongoing collections and reexamination of material already in museum collections are slowly increasing the number of known species from that coast, though it will probably never become large. Material of two species, both new to the fauna of Costa Rica, had been collected as parasites of two crabs in the anomuran family Porcellanidae on the Pacific coast of Costa Rica and were housed in the collection of the Museo de Zoología, Universidad de Costa Rica (designated UCR). One proved to belong to a species earlier recorded from elsewhere, while the second had previously been recorded but not described. Another specimen from California, in the collection of the National Museum of Natural History, Smithsonian Institution (designated USNM), for over 50 years, represents a new species in a new genus.

Systematics

Family Bopyridae, Rafinesque, 1815

Subfamily Pseudioninae R. Codreanu, 1967

Genus *Aporobopyrus* Nobili, 1906

Type-species, by monotypy, *Aporobopyrus aduliticus* Nobili, 1906. Number of valid species hitherto described: 19. Known distribution: Red Sea; Pakistan; Japan; Okinawa; Hong Kong; Moluccas; Amboina; California to Mexico; Gulf of Mexico; Caribbean Sea; Brazil; West Africa. Hosts: Various genera, nearly all in anomuran family Porcellanidae.

Discussion

The genus *Aporobopyrus* was established by Nobili (1906) for its type-species *A. aduliticus* Nobili, 1906, a parasite of *Petrolisthes rufescens* Heller in the Red Sea. Nobili's (1906) original description of *A. aduliticus* was carefully prepared, so it has been easy to assign subsequently described species to the genus. However, because of its close similarity to the rather ill-defined genus *Pseudione* Kossmann, 1881, some species subsequently considered to belong to *Aporobopyrus* were originally described as species of *Pseudione*. Bourdon (1976) redescribed several species of *Aporobopyrus*; and Adkison (1988) rediagnosed the genus, transferred three species into it from *Pseudione* and incorporated the genus *Pleurocryptosa* Nierstrasz and Brender à Brandis, 1929, and its five described species into it. With the description of the new species below, there are now 21 recognized species of *Aporobopyrus* world-wide, all but one infesting porcellanid crabs. Of these, three species have been previously reported from the eastern Pacific. *Aporobopyrus muguensis* Shiino, 1964, is known from California, as a parasite of *Pachycheles rudis* Stimpson and *P. pubescens* Holmes (Shiino 1964, Van Wyk 1982, Sassaman 1985) and the west coast of Mexico (Campos and Rosa de Campos 1989). Originally described from Japan by Shiino (1934), *A. oviformis* Shiino, 1934, was later reported to infest *Pachycheles pubescens* Holmes at Point Mugu, California (Shiino 1964). Finally, *A. trilobatus* (Nierstrasz and Brender à Brandis, 1925) was originally described under the name *Pseudione trilobata* as a parasite of *Pisosoma angustifrons* Benedict [now *Neopisosoma angustifrons* (Benedict)] at Curaçao in the Caribbean Sea (Nierstrasz and Brender à Brandis 1925); Bourdon (1976) reported it as a parasite of *Petrolisthes hians* Nobili at Zihuatenejo Bay on the west coast of Mexico, and its known range is now extended to the west coast of Costa Rica.

Aporobopyrus bourdonis, new species

Fig. 1.

"[A] bopyrid."–Haig 1968: 61 [Chamela Bay, Jalisco, Mexico, 19°31′N, 105°02′W; infesting *Petrolisthes edwardsii* (de Saussure)].

"Bopyré indéterminé (J. Haig)."–Bourdon 1976: 236–238, 241; fig. 43 [Study of material reported above].

"Pseudioninae, gen. sp.?"–Salazar-Vallejo and Leija-Tristán 1989: 430 [No new material; citation of above record].

? "[I]sopod bopyrids" pro parte.–Lazarus-Agudelo & Roccatagliata, 2007: 109 [Pacific coast of Colombia; infesting *Petrolisthes edwardsii* (de Saussure)].

Material examined. Infesting *Petrolisthes edwardsii* (de Saussure, 1853). Near Isla Juanilla, Area Conservación de Jurquillal, Guanacaste, Costa Rica, 10°59′N, 85°43′W. 1♀, holotype; 1 ♂, allotype. Museo de Zoología, UCR 2014-19.

Description of holotype female (Fig. 1A–H)

Length (exclusive of uropods) 2.47 mm, maximal width 1.62 mm, head length 0.68 mm, head width 0.98 mm, pleon length 0.54 mm. Body distortion 30°. All segments and body regions distinct (Fig. 1A, B). No pigmentation except for minute eyespots and tiny spots near sides of dorsal surfaces of some pereomeres and first pleomere.

Head broadly rounded anteriorly, greatly extended from body, produced into slightly curved right angle posteriorly. Fairly short but broad frontal lamina covering all of front margin. Two tiny dark eyespots near sides of anterior part of head. Antennae of three

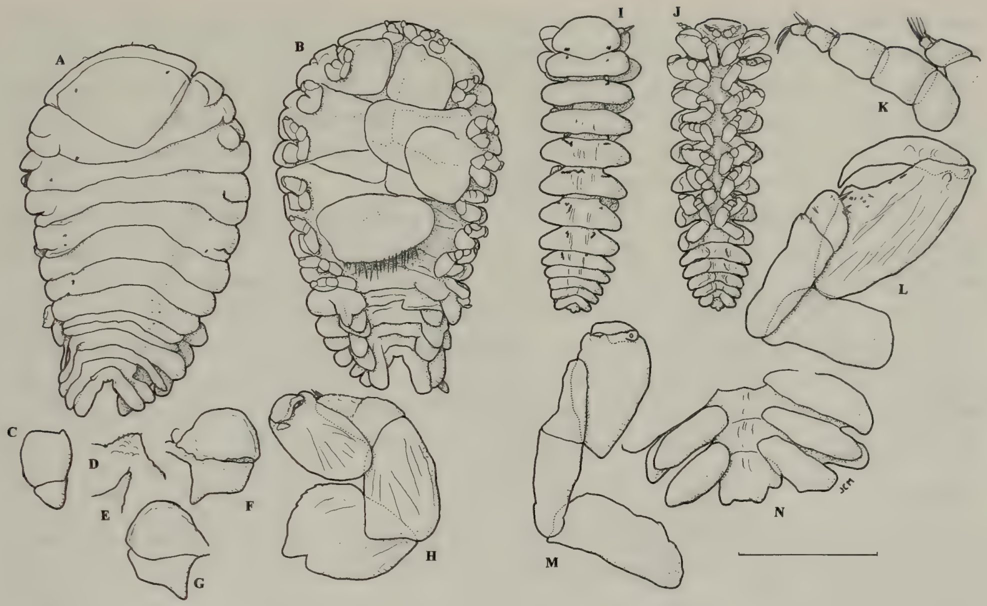


Fig. 1. *Aporobopyrus bourdonis*, new species. A–H, Holotype female. I–N, Allotype male. A. Dorsal view. B. Ventral view. C. Right maxilliped. D. Palp of same. E. Spur of same. F Right oostegite 1, external. G. Same, internal. H. Right pereopod 1. I. Dorsal view. J. Ventral view. K. Right antennae. L. Left pereopod 1. M. Left pereopod 7. N. End of pleon in ventral view. Scale: 1.00 mm for A, B, I, J; 0.87 mm for C, F, G; 0.17 mm for D, E, H, K–N.

articles apiece, those of both pairs equally large and extending only very slightly beyond margin of head. Maxilliped (Fig. 1C) subovate in outline, its anteromedial corner produced into small and completely nonarticulating palp (Fig. 1D), its posterior article extended anteromedially into slender sharp plectron (Fig. 1E).

Pereon with pereomeres all of about same length, broadest across second pereomere and tapering smoothly behind that; all pereomeres deeply separated laterally; pereomeres 1–4 bearing tergal plates on both sides. Oostegites almost completely enclosing brood pouch; oostegite 1 (Fig. 1F, G) semicircular anteriorly, extended into short straight-sided triangular point posterolaterally, with slightly sinuate flap overhanging separating groove; fifth oostegite with row of long setae along posterior margin. Pereopods (Fig. 1H) all of about same size and similar structure; all articles distinct, dactyli reduced, their short tips inserted into cuplike receptacles produced on anterolateral corners of propodi; distal ends of meri sparsely setose; bases lacking carinae.

Pleon of six pleomeres, all shorter than pereomeres, and all of about same length, progressively narrower posteriorly; first five produced into long lanceolate lateral plates on both sides, most directed posteriorly; final pleomere produced into similar long posterolaterally directed uropods. Five pairs of biramous pleopods, their endopodites as laterally directed ovate lobes, endopodites oblong and posteriorly directed; all pleopods larger on longer side of body. Last pleomere produced into long nonarticulating uropods of same structure as lateral plates.

Description of allotype male (Fig. 1I–N)

Length 2.37 mm, maximal width 0.73 mm, head length 0.35 mm, head width 0.55 mm, pleon length 9.51 mm. All body regions and segments distinct (Fig. 1I, J). Tiny black eyes near posterior borders of head, irregularly shaped dark splotches near dorsal anterolateral margins of several pereomeres and first pleomere.

Head slightly narrower than first pereomere and extending clearly forward from that segment, roughly semicircular but with posterior margin slightly convex. Antennae (Fig. 1K, L) reduced and not reaching to margins of head, of three and five articles respectively, some articles sparsely setose distally.

Pereon of seven deeply separated pereomeres, its sides nearly parallel. No midventral tubercles. Pereopods all relatively large, some extending beyond sides of body; dactyli and propodi of first two pairs much larger than others, all pereopods progressively somewhat smaller overall posteriorly; meri and carpi of all pereopods fused.

Pleon of six pleomeres, all of about same length but each narrower than preceding, sides of pleomeres 1–5 forming straight converging lines, pleomere 6 greatly reduced and embedded in posterior margin of preceding one. Pleopods as broad sessile oval swellings on pleomeres 1–5. No uropods or conspicuous anal cone (Fig. 2N).

Etymology

Name *bourdonis*, Latin genitive singular of third declension noun, selected in honor of Roland Bourdon, the noted authority on the Bopyridae, who first studied this species but did not name it.

Discussion

The descriptive notes and illustration provided by Bourdon (1976) are detailed enough to provide confidence that this is the same species that he was studying. *Aporobopyrus bourdonis* most closely resembles *A. muguensis* Shiino, 1964, reported below, in both sexes and is easily distinguished from all other species of the genus. Specifically, females of both *A. bourdonis* and *A. muguensis* have very broad extended heads and long slender uropods, while males of both species are more than three times as long as broad, with all pereomeres deeply separated and of nearly the same width and the sides of the first one not curved forward (Shiino, 1964). The female of *A. muguensis* differs from that of *A. bourdonis* in that the frontal lamina of its head is not demarcated, its body is more rounded, it has dorsally visible coxal plates on more pereomeres, its pleopodal endopodites are larger than its exopodites, and its uropods touch each other medially. The male of *A. muguensis*, in contrast with that of *A. bourdonis*, has a shorter head and its posterior margin produced into posterolateral lobes extending beyond a prominent anal cone. *A. bourdonis* is the only species of bopyrid known to infest *Petrolisthes edwardsii*. Lazarus-Agudelo & Roccatagliata (2007), in a brief abstract, report finding 44 infested individuals of *P. edwardsii* on the Pacific coast of Colombia but they have not reported the identity of the parasites, which may or may not be *A. bourdonis*.

Aporobopyrus muguensis Shiino, 1964

Fig. 2.

Aporobopyrus muguensis Shiino, 1964: 20–22; fig. 1 [Point Mugu, California; infesting *Pachycheles rudis* Stimpson].–Schultz, 1969: 315; fig. 500(b).–Markham, 1975: 265; table I.– Miller, 1975: 285, 286, 305; pl. 64; fig. 15.–Bourdon, 1976: 166, 187.–Van Wyk, 1980: 889 [San Simeon, California; infesting *P. rudis*; study of effects on host].–Lee and Miller, 1980: 544; pl. 57; photograph 21.11 [Pacific Grove and Dillon Beach, California; infesting *P. rudis*].–Haig and Abbott, 1980: 589.–Wallerstein, 1980: 235.–Hart, 1982: 32.–Van Wyk, 1982: 459–471; figs. 1–5; tables

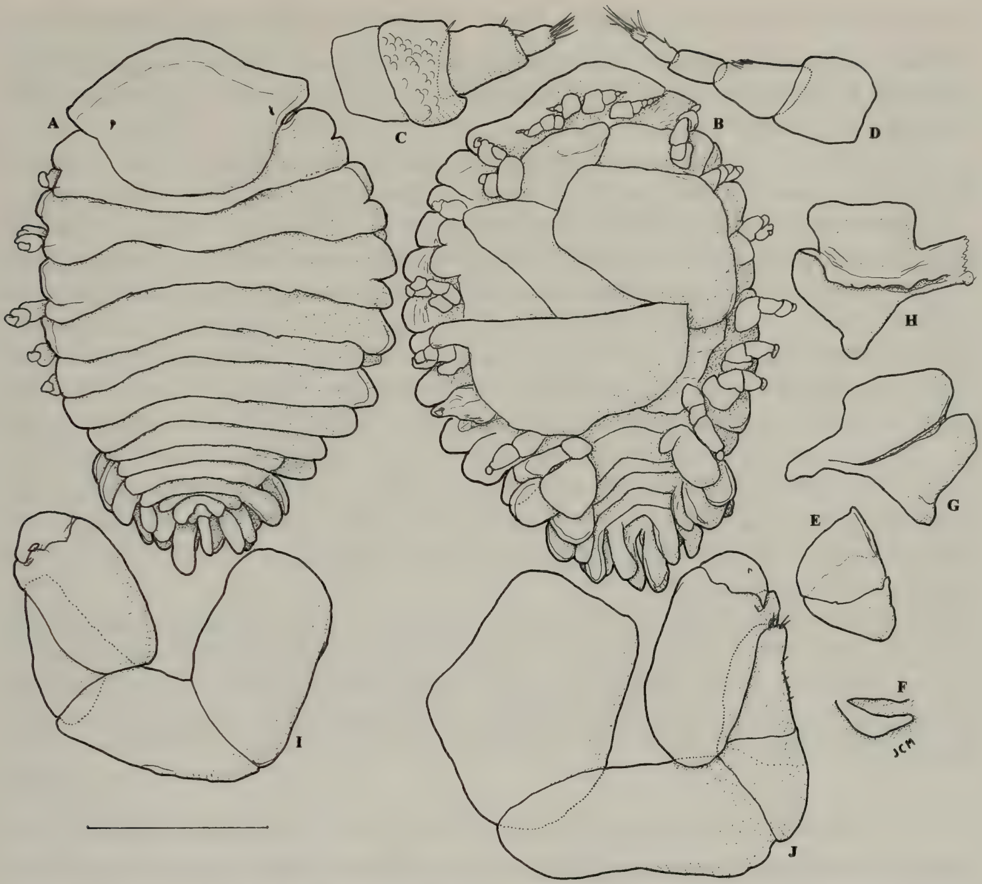


Fig. 2. *Aporobopyrus muguensis* Shiino, 1964, female. A. Dorsal view. B. Ventral view. C. Left antenna 1. D. Right antenna 2. E. Right maxilliped, external. F. Barbula, right side. G. Right oostegite 1, external. H. Same, internal. I. Right pereopod 1. J. Right pereopod 7. Scale: 1.00 mm for A, B; 0.87 mm for E, G, H; 0.34 mm for F; 0.17 mm for C, D, I, J.

1–3 [San Simeon, California; infesting *P. rudis*; study of effects on host].–Sassaman et al., 1984: 651, 653 [Monterey, California; infesting *P. rudis* and *P. pubescens* Holmes].–Austin, 1985: 587.–Sassaman, 1985: 778, 782, 785, 787 [Monterey, California; infesting *P. rudis* and *P. pubescens*; bearing hyperparasite *Cabirops montereyensis* n. sp.].–O'Brien and van Wyk, 1985: 196; 197; 210 fig. 2 [San Simeon, California; infesting *P. rudis*; study of effects on host].–Campos-Gonzalez and Campoy-Favela, 1987: 39, 40–41, 42, 47; fig. 1.–Markham, 1988: 27.–Campos and Rosa de Campos, 1989: 33; table 2.–Jay, 1989: 75.–Salazar-Vallejo and Leija-Tristan, 1989: 429.–Markham, 1992: 3; table 1.–Sassaman, 1992: 575, 576 [Malibu, California; infesting *P. holosericus* Schmitt; hyperparasitized].–Cash and Bauer, 1993: 120.–Oliveira and Masunari, 1998: 1708.–Brusca et al., 2001: 22.–McDermott, 2002: 39.–Brusca et al., 2007: 535.–Kuris et al., 2007: 654.

Aporobopyrus.–Carlton and Kuris, 1975: 410.–Sassaman, 1985; 783.

Aporobopyrus m guensis [sic].–Bourdon, 1976: 240.

Aporobopyrus muquensis [sic].–Campos and Rosa de Campos, 1989: 30.

Aparobopyrus [sic].–Raibaut and Trilles, 1993: 423.

Aporobopyrus mugensis [sic].–Espinosa-Pérez and Hendrickx, 2006: 236; appendix 1.

Material examined. Infesting *Pachycheles pubescens* Holmes, 1900. In kelp holdfast, Monterey, California, 36°35′N, 121°55′W, M. Morris coll. #82-025, 13 March 1982: 1♀, USNM.

Descriptive notes.—The present female is proportionately somewhat wider (Fig. 2A, B) than the type. Its head (Fig. 2A) is extended farther laterally, but its tiny eyes are very similar. The antennae (Fig. 2C, D), not previously mentioned, are about equally long, of four and five articles respectively, the first one being broader. The maxilliped (Fig. 2E) is only slightly produced into a small nonarticulating palp and a long slender plectron. The barbula (Fig. 2F) bears only one long slender projection on each side. Like that of the type, the pereon is little ornamented. The first oostegite (Fig. 2G, H) is much broader than long and produced into a blunt posterior projection; its internal ridge is only slightly ornamented. The pereopods (Fig. 2I, J) are slightly larger posteriorly, the meri and carpi of the anterior ones being fused. The pleopods are similar to those of the type, their exopodites extending considerably beyond the margins of the pleomeres, the subcircular endopodites not covering the central region of the dorsal surface of the pleon. The uropods are less visible dorsally than in the type but highly conspicuous ventrally.

Despite having been collected several times along the coast of California, *Aporobopyrus muguensis* has not been further described since the original account of Shiino (1964), two of whose drawings Miller (1975) reproduced. Lee and Miller (1980) presented an original drawing and a color photograph of *A. muguensis*, but neither contains enough detail to be diagnostic to species.

Aporobopyrus trilobatus (Nierstrasz and Brender à Brandis, 1925)

Pseudione trilobata Nierstrasz and Brender à Brandis 1925: 2–3, 7; figs. 7–10 [Spaansebaai, Curaçao, Netherlands Antilles; infesting *Pisosoma angustifrons* Benedict {=*Neopisosoma angustiforns* (Benedict)}].—Monod 1933: 227.—Shiino 1933: 271.—Schultz 1969: 325; fig. 519.—Bourdon 1976: 165, 167–171, 240, 241; figs. 1–3 [Bahía de Zihuatenejo, Guerrero, Mexico, 17°37′N, 101°34′W, infesting *Petrolisthes hians* Nobili; diagnosis and redescription].—Markham 1978: 489.—Markham 1988: 3, 4, 17–18; fig. 7 [Piscaderabaai, Curaçao; infesting *Pachycheles pilosus* (H. Milne Edwards); synonymy and descriptive notes].—Salazar-Vallejo and Leija-Tristán 1989: 430.—Campos and Rosa de Campos 1989: 33; table 2.

"[A] bopyrid": Haig 1968: 67 [Bahía de Zihuatenejo, Guerrero, Mexico, 17°37′N, 101°34′W, infesting *Petrolisthes hians* Nobili; material examined and identified by Bourdon (1976) above].

Pseudione tridentata [sic]: Markham 1988: 56; table 1.

Pseudione trilobotata [sic]: Adkison 1988: 579 [Transferred to genus *Aporobopyrus*].

Aporobopyrus trilobotata [sic]: Adkison 1988: 579.

Aporobopyrus trilobata [sic]: Markham 1992: 3; table 1.–Espinosa-Pérez & Hendrickx 2001: 50.

Material examined. Infesting *Petrolisthes ortmanni* Nobili, 1901. Lower intertidal, Cambutal, near Roca Punta Domenical, Puntarenas, Costa Rica, 09°13′N, 83°50′W, 16 May 1995, J. M. Montoya coll. & det. of host: 1♀, immature; 1♂, UCR 2032-14.

Descriptive notes on female

Length (exclusive of frontal lamina and uropods) 3.25 mm, maximal width 1.74 mm, head length 0.81 mm, head length 1.01 mm, pleon length 0.70 mm, body axis distortion 2°. Body outline irregularly oval. All body regions and pereomeres distinct, some pleomeres fused. No pigmentation except for minute eyespots.

Head greatly extended and strongly separated from anterior of pereon, rounded and markedly convex both anteriorly and posteriorly. Short frontal margin completely covering anterior edge and extending to turning point between anterior and posterior curves. Eyes as single tiny dark spots near lateral margins. Antennae extending obliquely beyond anterior margin of head, each of three articles. Maxilliped of subrectangular anterior articles and much smaller subtriangular posterior article; anteromedial corner produced into blunt minutely setose point but not distinct palp; plectron acutely pointed, markedly extended anteriorly and tightly pressed against margin of anterior article. Barbula with single short lanceolate unornamented projection on each side.

Pereon with nearly parallel sides, most pereomeres about same length, their sides irregular; third pereomere slightly longer and broader than others. Oostegites large relative to body size, almost completely covering whole body ventrally and somewhat visible dorsally; oostegite 1 semicircular anteriorly, produced into posteriorly extended slender terete posterolateral projection, internal ridge bearing only sparse simple teeth; other oostegites strongly overlapping and fully enclosing brood pouch. Pereopods all of about same size, with all articles distinct, dactyli bluntly pointed, carpi heavily setose, bases noncarinate.

Pleon of five incompletely separated pleomeres, first four bearing very slender biramous pleopods, their endopodites much smaller. End of pleon produced into similar uniramous uropods.

Descriptive notes on male

Length 1.98 mm, maximal width 0.56 mm, head length 0.26 mm, head width 0.37 mm, pleon length 0.47 mm. All body regions and segments distinctly set apart. Small eyespots and scattered small splotches on dorsal surfaces of some pereomeres and pleomeres.

Head semicircular, straight posteriorly, abruptly narrower than first pereomere. Eyespots as single small points near posterolateral corners. Antennae of three and five articles respectively, each bearing long setae distally, few elsewhere.

All pereomeres deeply separated laterally and about same size, so sides of pereomeres almost parallel. Pereopods all strongly developed. In first two pairs, dactyli long and curved, their tips almost reaching serrated setose distal margins of respective carpi; propodi greatly enlarged and resting on respective bases; meri and carpi fused. Posterior pereopods with dactyli and propodi more reduced, other articles elongate, carpi and meri separate.

Pleon of six distinct pleomeres, each narrower than preceding one. Pleopods as five pairs of sessile uniramous lanceolate flaps. Final pleomere as reduced triangular pleotelson with traces of tiny uropods on ventral surface, reduced anal cone in middle.

Remarks

This is the first record of bopyrid infestation of *Petrolisthes ortmanni*, a species known from the Gulf of California to western South America (Boschi 2000, Brusca 1980). Because the female is immature, as indicated by its lack of eggs and relatively slender body (and possibly also the very slight distortion of its body axis and the disheveled appearance of its pleopods), there remains some slight doubt about the identity of this material. Nonetheless, the female's barbula, maxilliped and first oostegite conform well with those previously recorded for *A. trilobatus*, and the present male agrees well with those reported by Bourdon (1976). For these reasons, I consider it most likely to belong to that species. It is uncertain why the gender of the species name has not previously been corrected to match that of its current genus, but this appears to be the first use of the form *trilobatus*.

Genus *Discomorphus*, new genus

Diagnosis: Female: Broader than long, only slightly distorted. Head broader than long, completely covered anteriorly by short frontal lamina, barbula nearly undeveloped; maxilliped bearing prominent articulating palp. Pereomeres all of nearly same length, their coxal plates reduced or absent; long narrow oostegites extending clear across brood pouch and greatly overlapping opposite ones. Pleon nearly straight across posterior margin, of six pleomeres, first five produced into extended lateral plates, sixth as small embedded pleotelson; five pairs of biramous pleopods, exopodites of first three greatly expanded; no uropods. Male: Unknown. Host: Genus *Petrolisthes*. Type-species, by present designation, *Discomorphus magnifoliatus* n. sp.

Etymology: Greek stems *Disco-* ("circle") + *morphus* ("form") selected in reference to outline of female's body and to reflect name of similar-appearing female of genus *Orbimorphus* Richardson. Gender masculine.

Discomorphus magnifoliatus n. sp.

Fig. 3.

Material examined. Infesting *Petrolisthes cinctipes* (Randall, 1839). Intertidal, Mussel Point, Pacific Grove, Monterey County, California, 36°38′N, 121°56′W, 19 June 1951, C. Hand coll.: 1♀, holotype, USNM 154611.

Description of holotype female (Fig. 3)

Length (exclusive of pleopods) 5.32 mm, maximal width 5.46 mm, head length 1.84 mm, head width 2.91 mm, pleon length 0.96 mm. Body distortion 12°. All segments and body regions distinct (Fig. 3A, B). Body outline nearly circular except posterior border, exclusive of pleopods, almost straight; middorsal region of last pereomere and of all pleomeres markedly swollen dorsally. No pigmentation.

Head suboval, broadly rounded both anteriorly and posterioly, much broader than long, slightly extended from body. Fairly short but broad frontal lamina covering all of front margin and beyond on both sides. No eyespots. Antennae (Fig. 3C) of three and five articles respectively, those of both pairs equally large, only those of second pair extending very slightly beyond margin of head. Barbula (Fig. 3D) with only one tiny projection on each side. Maxilliped (Fig. 3E) subovate in outline, its anteromedial corner produced into prominent, extended and distinctly articulating palp, its posterior article extended anteromedially into slender sharp plectron.

Pereon with pereomeres all of about same length, broadest across third to fifth pereomeres; all pereomeres deeply separated laterally; pereomeres 1–4 bearing tergal plates on both sides. Oostegites almost completely enclosing brood pouch; oostegite 1 (Fig. 3F, G) semicircular anteriorly, extended into short straight-sided triangular point posterolaterally, with slightly sinuate flap overhanging separating groove; fifth oostegite with row of long setae along posterior margin. Pereopods (Fig. 3H, J) all of similar structure but nearly doubling in size posteriorly; all articles distinct; dactyli reduced, their short tips (Fig. 3I, K) inserted into obscure cuplike receptacles on anterior margins of propodi; distal ends of meri sparsely setose; bases of posterior pereopods carinate.

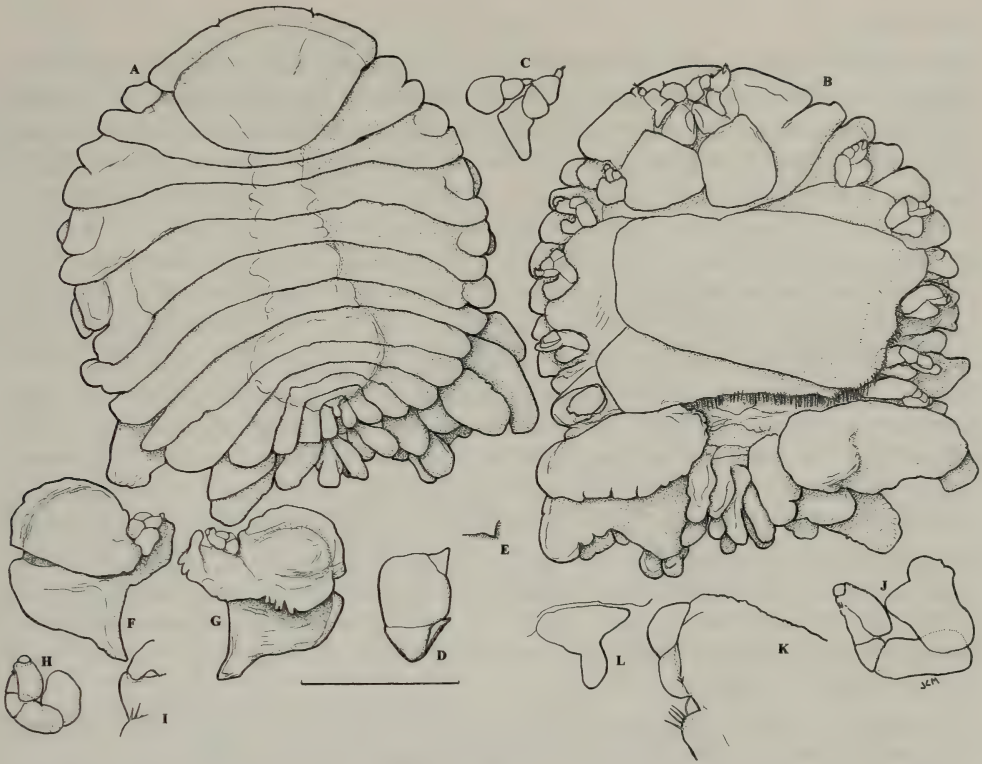


Fig. 3. *Discomorphus magnifoliatus* new species, Holotype female. A. Dorsal view. B. Ventral view. C. Left antennae. D. Right maxilliped. E. Left side of barbula. F. Right oostegite 1, external. G. Same, internal. H. Right pereopod 1. I. Distal region of same. J. Right pereopod 7. K. Distal region of same. L. Pleotelson, sixth pleomere. Scale: 2.00 mm for A, B, D–G; 1.00 mm for C; 0.87 mm for H, J; 0.40 mm for L; 0.17 mm for I, K.

Pleon of six pleomeres, first five of about same length but each much narrower than preceding. Lateral plates extended far to sides on pleomere 1, making that segment as broad as final pereomere, others progressively angled farther back until those on pleomere 5 extending straight back; edges of lateral plates on sides of pleomeres 1–3 forming curved converging lines, those on pleomeres 3–6 nearly straight across back of body. Five pairs of biramous pleopods nearly symmetrical on opposite sides of body, endopodites of first three pairs greatly expanded into large subrectangular fleshy lobes extending far to sides, other exopodites and all endopodites much reduced and mostly extending posteriorly somewhat beyond margins of lateral plates; pleopods covering all but small medioanterior region of pleon ventrally. Pleomere 6 (Fig. 3L) hastate, its anterior region nearly as broad as whole article, posterior half only one-third that broad, lateral plates of fifth pleomere extending far beyond it on both sides. No uropods.

Male unknown.

Etymology

Latin adjective *magnifoliatus*, "large-leafed," in reference to greatly expanded exopodites of female's first three pairs of pleopods.

Discussion

The female of *Discomorphus magnifoliatus* n. sp. superficially looks quite similar to *Orbimorphus constrictus* Richardson, 1910, a parasite of *Petrolisthes armatus* (Gibbes) collected only once, on the coast of Peru. *Orbimorphus constrictus* remains the sole known species of the genus *Orbimorphus*, as described by Richardson (1910) and redescribed by Bourdon (1976). *Discomorphus magnifoliatus* differs in details sufficiently significant to make its inclusion in the genus *Orbimorphus* untenable. Specifically, its body is proportionately much broader; its barbula is very simple, rather than having two well-developed projections on each side; the palp articulates distinctly with the maxilliped, rather than being fused with it; it has six pleomeres, not five, the sixth being much reduced, inset and of unique shape; and the greatly expanded endopodites of the pleopods are like none known for any other bopyrid species. It is regrettable that the male of the new species is unknown, but, despite its absence, the distinctive characters of the female justify the placement of the species in a new genus. In a recent report on a newly erected genus of pseudionine bopyrid infesting a galatheid host in the Gulf of California, Román-Contreras and Boyko (2007) presented a very useful tabulation of the characters diagnostic for all 22 genera currently known to include parasites of galatheoids world-wide. Comparison of the characters of the female of *Discomorphus* n. g. with those in that table makes it immediately evident that it does not conform with the diagnosis of any previously known genus of galatheoid-infesting bopyrid and so becomes the 23rd such genus to belong to that group.

This is the first record of bopyrid infestation of *Petrolisthes cinctipes*, which is reported from British Columbia to southern California (Haig and Abbott, 1980).

Remarks on host porcellanids

In his valuable catalog of marine decapod crustaceans of the Americas, Boschi (2000) lists 78 species in seven genera of the family Porcellanidae recorded from the Pacific coasts of North and South America. Until very recently, of those, only seven species in two genera have been known to serve as hosts of bopyrid isopods, all of them documented above. Species on that list herein newly added are *Petrolisthes cinctipes* and *P. ortmanni*. The infested species are: *Pachycheles holosericus* (bearing *Aporobopyrus muguensis* in southern California); *P. pubescens* (bearing *A. muguensis* in central California and *A. oviformis* Shiino in southern California); *P. rudis* (bearing *Aporobopyrus muguensis* in central to southern California); *Petrolisthes cinctipes* (bearing *Discomorphus magnifoliatus* in central California); *P. edwardsii* (bearing *Aporobopyrus bourdonis* in Puntarenas, Costa Rica); *P. hians* (bearing *Aporobopyrus trilobatus* in Guerrero, Mexico); and *P. ortmanni* (bearing *A. trilobatus* in Puntarenas, Costa Rica). Lazarus-Agudelo & Roccatagliata (2007) now report the collection of bopyrid-infested individuals of 12 species of porcellanids on the Pacific coast of Colombia, the first such record from any part of the Pacific coast of South America. Unfortunately, their preliminary account, an abstract only, does not name any of the parasites. The hosts, five *Petrolisthes* spp., three *Pachycheles* spp., two *Neopisosoma* spp., and one species each in the genera *Megalobrachium* and *Pisidia*, are all new host records. Whether the parasites they bear belong to one or more of the species considered above is unknown. *Petrolisthes ortmanni*, newly documented as a bopyrid host in this report, is also included in the list by Lazarus-Agudelo & Roccatagliata (2007), and that citation is accordingly included as a possible synonym of the parasite *Aporobopyrus trilobatus*, above.

Acknowledgments

Rita Vargas, Universidad de Costa Rica (abbreviated UCR), provided much of the material for examination and performed essential curatorial services. Marilyn Schotte, National Museum of Natural History, Smithsonian Institution (abbreviated USNM) made available material from that institution. This is publication number 27 of the Arch Cape Marine Laboratory.

Literature Cited

Adkison, D.L. 1988. *Pseudione parviramus* and *Aporobopyrus collardi*, two new species of Bopyridae (Isopoda: Epicaridea) from the Gulf of Mexico. Proc. Biol. Soc. Washington, 101:576–584.

Austin, W.C. 1985. An annotated checklist of marine invertebrates of the cold temperate northeast Pacific. Khoyatan Marine Laboratory, Cowichan Bay, British Columbia. xiv + 683 pp.

Boschi, E.E. 2000. Species of decapod crustaceans and their distribution in the American marine zoogeographic provinces. Rev. Invest. Desarr. Pesqu., 13:1–136.

Bourdon, R. 1976. Les bopyres des porcellanes. Bull. Mus. Natl. Hist. Nat., Paris (3) (359), Zool., 252: 165–245.

Brusca, R.C. 1980. Common intertidal invertebrates of the Gulf of California. Second edition. Univ. Arizona Press, Tucson, Arizona. xx + 513 pp.

———, V.R. Coelho, and S. Taiti. 2001. A guide to the marine isopods of coastal California. Electronic Publication. http://phylogeny.arizona.edu/tree/eukaryotes/ animals/arthropoda/ crustacea /isopoda/ isopod_;ichen/bruscapeet. html. Pp. 1–43.

———, ———, and ———. 2007. Isopoda. Pp. 503–542 *in*: The Light and Smith Manual: Intertidal invertebrates from central California to Oregon. Fourth Edition, completely revised and expanded. (J.T. Carlton, ed.), Univ. California Press, xvii + 1001 pp.

Campos, E. and A. Rosa de Campos. 1989. Range extensions of decapod crustaceans from Bahía Tortugas and vicinity, Baja California Sur, Mexico. Calif. Fish and Game, 75(3):174–177.

Campos-Gonzalez, E. and J.R. Campoy-Favela. 1987. Epicarídeos de Baja California I. Primer registro y notas bioecológicas de dos Bopyridae y un Cryptoniscidae (Crustacea, Isopoda) para México. (Epicarideans from Baja California I. First record and bioecological notes on two Bopyridae and one Cryptoniscidae (Crustacea, Isopoda) for Mexico.) Ciencias Marinas, 13(3):39–48.

Carlton, J.T. and A.M. Kuris. 1975. Keys to decapod Crustacea. Pp. 385–412 *in* Light's manual: Intertidal invertebrates of the central California coast. (R.I. Smith and J.T. Carlton, eds.), Univ. Calif. Press, xviii + 716 pp.

Cash, C.E. and R.T. Bauer. 1993. Adaptations of the branchial ectoparasite *Probopyrus pandalicola* (Isopoda: Bopyridae) for survival and reproduction related to ecdysis of the host, *Palaemonetes pugio* (Caridea: Palaemonidae). J. Crust. Biol., 13:111–124.

Espinosa-Pérez, M.d.C. and M.E. Hendrickx. 2001. Checklist of isopods (Crustacea: Peracarida: Isopoda) from the eastern tropical Pacific. Belgian J. Zool., 131:43–55.

——— and ———. 2006. A comparative analysis of biodiversity and distribution of shallow-water marine isopods (Crustacea: Isopoda) from polar and temperate waters in the East Pacific. Belgian J. Zool., 136:219–247.

Haig, J. 1968. Eastern Pacific Expeditions of the New York Zoological Society. Porcellanid crabs (Crustacea Anomura) from the west coast of tropical America. Zoologica, 53:57–74.

——— and D.P. Abbott. 1980. Macrura and Anomura: The ghost shrimps, hermit crabs, and allies. Chapter 24, Pp. 577–593 *in* Intertidal invertebrates of California. (R.H. Morris, D.P. Abbott, and E.C. Haderlie, eds.), Stanford Univ. Press, ix + 690 pp.

Jay, C.V. 1989. Prevalence, size and fecundity of the parasitic isopod *Argeia pugettensis* on its host shrimp *Crangon franciscorum*. American Midland Naturalist, 121:68–77.

Kuris, A.M., P.S. Sadeghian, J.T. Carlton, and E. Campos. 2007. Decapoda. Pp. 632–656 *in* (J.T. Carlton, ed.), The Light and Smith Manual: Intertidal invertebrates from central California to Oregon. Fourth Edition, completely revised and expanded. Univ. California Press, xvii + 1001 pp.

Lazarus-Agudelo, J.F. and D. Roccatagliata. 2007. On the bopyrid isopods from the Colombian Pacific coast. [Abstract]. The Crustacean Society Mid-year Meeting. La Serena - Coquimbo - Chile – 14–17 October 2007. Program and Abstracts. p. 109.

Lee, W.L. and M.A. Miller. 1980. Isopoda and Tanaidacea: The isopods and allies. Chapter 21, Pp. 536–558 *in* Intertidal invertebrates of California. (R.H. Morris, D.P. Abbott, and E.C. Haderlie, eds.), Stanford Univ. Press, ix + 690 pp.

Markham, J.C. 1975. Bopyrid isopods infesting porcellanid crabs in the northwestern Atlantic. Crustaceana, 28:257–270.

———. 1978. A new genus and species of bopyrid isopod parasitic on the western Atlantic porcellanid *Pachycheles ackleianus* A. Milne Edwards. Proc. Biol. Soc. Washington, 91:483–489.

———. 1988. Descriptions and revisions of some species of Isopoda Bopyridae of the north western Atlantic Ocean. Zool. Verhand., 246:1–63.

———. 1992. The Isopoda Bopyridae of the eastern Pacific – missing or just hiding? Proc. San Diego Soc. Nat. Hist., 17:1–4.

McDermott, J.J. 2002. Relationships between the parasitic isopods *Stegias clibanarii* Richardson, 1904 and *Bopyrissa wolffi* Markham, 1978 (Bopyridae) and the intertidal hermit crab *Clibanarius tricolor* (Gibbes, 1850) (Anomura) in Bermuda. Ophelia, 56(1):33–42.

Miller, M.A. 1975. Phylum Arthropoda: Crustacea, Tanaidacea and Isopoda. Pp. 277–312 *in* Light's manual: Intertidal invertebrates of the central California coast. (R.I. Smith and J.T. Carlton, eds.), Univ. Calif. Press, xvii + 716 pp.

Monod, T. 1933. Mission Robert-Ph. Dollfus en Égypte. Tanaidacea et Isopoda. Mém. Inst. Égypte, 21: 161–264.

Nierstrasz, H.F. and G.A. Brender à Brandis. 1925. Bijdrage tot de kennis der fauna van Curaçao. Epicaridea. Bijdr. Dierk., 24:1–8.

Nobili, G. 1906. Nuovi Bopiridi. Atti Real. Accad. Sci. Torino, 41:1–18.

O'Brien, J. and P. Van Wyk. 1985. Effects of crustacean parasitic castrators (epicaridean isopods and rhizocephalan barnacles) on growth of crustacean hosts. Pp. 191–281 *in* Crustacean Issues 3: Factors in adult growth. (A.M. Wenner, ed.), Rotterdam: Balkema, xiii + 362 pp.

Oliveira, E. and S. Masunari. 1998. Population relationships between the parasite *Aporobopyrus curtatus* (Richardson, 1904) (Isopoda: Bopyridae) and one of its porcelain crab hosts *Petrolisthes armatus* (Gibbes, 1850) (Decapoda: Porcellanidae) from Farol Island, southern Brazil. J. Nat. Hist., 32: 1707–1717.

Raibaut, A. and J.P. Trilles. 1993. The sexuality of parasitic crustaceans. Advances in Parasitology, 32: 367–455.

Richardson, H. 1910. Report on isopods from Peru, collected by Dr. R. E. Coker. Proc. U. S. Natl. Mus., 38:79–85.

Román-Contreras, R. and C.B. Boyko. 2007. A new genus and species of bopyrid isopod infesting the crab *Munidopsis depressa* (Anomura: Galatheidae) from the Gulf of California, with notes on its ecology. J. Crust. Biol., 27(2):370–379.

Salazar-Vallejo, S.I. and A. Leija-Tristán. 1989. *Progebiophilus bruscai* n. sp., a new bopyrid isopod parasitic on the mud shrimp *Upogebia dawsoni* Williams (Thalassinidea) from the Gulf of California. Cah. Biol. Mar., 30(4):423–432.

Sassaman, C. 1985. *Cabirops montereyensis*, a new species of hyperparasitic isopod from Monterey Bay, California (Epicaridea, Cabiropsidae). Proc. Biol. Soc. Washington, 98:778–789.

———. 1992. Description of the mature female and epicaridium larva of *Cabirops montereyensis* Sassaman from southern California (Crustacea: Isopoda: Cabiropidae). Proc. Biol. Soc. Washington, 105(3):575–584.

———, G.A. Schultz, and R. Garthwaite. 1984. Host, synonomy, and parasitic incidence of *Bopyrella calmani* (Richardson) from central California (Isopoda: Epicaridea: Bopyridae). Proc. Biol. Soc. Washington, 97:645–654.

Schultz, G.A. 1969. How to know the marine isopod crustaceans. Dubuque, Iowa: Wm. C. Brown, vii + 359 pp.

Shiino, S.M. 1933. Bopyrids from Tanabe Bay. Mem. Coll. Sci., Kyoto Imp. Univ. (B) 8 (3, Art. 8):249–300.

———. 1934. Bopyrids from Tanabe Bay II. Mem. Coll. Sci., Kyoto Imp. Univ. (B) 9 (4, Art. 7):257–287.

———. 1964. On three bopyrid isopods from California. Rep. Fac. Fish., Pref. Univ. Mie, 5:19–25.

Van Wyk, P.M. 1980. Effects of a bopyrid isopod parasite on reproduction and growth of its porcellanid crab host [Abstract 901]. Amer. Zool., 20(4):889.

———. 1982. Inhibition of the growth and reproduction of the porcellanid crab *Pachycheles rudis* by the bopyrid isopod, *Aporobopyrus muguensis*. Parasitology, 85:459–473.

Wallerstein, B.R. 1980. Isopoda. Pp. 230–236 *in* A taxonomic listing of common marine invertebrate species from southern California. (D. Straughan and R.W. Klink, eds.), Tech. Rep. Allan Hancock Found. 3. vi + 281 pp.

Accepted for publication 11 December 2007.

Bull. Southern California Acad. Sci.
107(3), 2008, pp. 158–177

Genetic Variation in the Endangered *Astragalus jaegerianus* (Fabaceae, Papilionoideae): A Geographically Restricted Species

George F. Walker[1] and Anthony E. Metcalf

Department of Biology, California State University San Bernardino, San Bernardino, California 92407, USA

Abstract.—Knowledge of genetic variation and population structure is critically important in the conservation of endangered species. The level and partitioning of genetic variation in the narrow endemic *Astragalus jaegerianus* was investigated using DNA sequence data and AFLP markers. The DNA sequence data for the cpDNA *trnL-F* and nrDNA ITS regions were monomorphic for *A. jaegerianus* but polymorphic for two congeners, which suggest *A. jaegerianus* is genetically depauperate. On the other hand, the genome-wide survey using AFLP markers revealed substantial gene diversity (0.2660) and significant population structure (global $F_{ST} = 0.133$, $p < 0.01$). This level of gene diversity and its partitioning among populations is comparable to patterns for geographically widespread species. These findings also challenge the hypothesis that levels of gene diversity are best predicted by population size. In this case, levels of gene diversity within populations are significantly correlated with population density, while geographic distances and gene flow explain patterns of population structure. These results suggest a breeding strategy for *A. jaegerianus* as a facultative outcrosser that relies more on outcrossing in areas of high plant density and less so in areas of low plant density. Conservation measures are recommended that include monitoring population genetics, numbers of individuals, and population densities.

Genetic variation is recognized as an important raw material of evolutionary and ecological processes in natural populations (Wright 1931; Karron et al. 1988; Clegg 1990; Epperson 1990; Frankham et al. 2002; Conner and Hartl 2004; but see Ackerly 2003). Effective conservation strategies for geographically restricted species require information about the level of genetic variation present and whether genetically distinct subpopulations exist. This information can aid management efforts by suggesting number of individuals and populations needed for the conservation of the species (Mace and Lande 1991; Lynch 1996; Nunney 2000; Frankham et al. 2002). The federally endangered *Astragalus jaegerianus* Munz (Fabaceae) is a narrow endemic of the Mojave Desert (southern California; USA) with small populations of relatively few individuals (U.S. Fish and Wildlife Service 2001). It is restricted within a range of 300 km^2 but only occupies approximately 85 km^2 of that habitat. In an intensive survey conducted in 2001, this species had an estimated population size of 5,700 plants (U.S. Fish and Wildlife Service 2001; Charis Professional Services Corporation [Charis] 2002; M. Hessing, Charis, unpublished data). To assist conservation efforts for *Astragalus jaegerianus*, we investigated the level of genetic variation and its partitioning within the range of this species.

---

[1] Email: gwalker@sheridan.edu Present address: Sheridan College, P.O. Box 1500, 3059 Coffeen Ave., Sheridan, WY 82801 USA

Population genetic theory predicts that geographically widespread plant species with large populations should typically possess higher levels of genetic variation than do geographically restricted species with small populations (reviewed in Hamrick et al. 1979; Hamrick and Godt 1989; Karron 1991; Soltis and Soltis 1991; Godt et al. 1996; Frankham et al. 2002; Avise 2004). This is predicated on the premise that species with small populations and few individuals are subject to genetic drift that reduces genetic variation (Barrett and Kohn 1991; Ellstrand and Elam 1993). Other factors affecting low genetic variation in restricted species may include strong directional selection and increased inbreeding (Karron 1991). While such reviews provide valuable comparisons of levels of genetic variation among widespread and restricted species, the effects of rarity on genetic variability may be confounded by other variables, such as historic demographic changes in population size, the lack of shared evolutionary histories, and sampling at dissimilar spatial scales (Karron 1987b; Gitzendanner and Soltis 2000; Cole 2003). For instance, in their review of the literature on levels of genetic variability between congeners, Gitzendanner and Soltis (2000) did find a pattern of higher levels of genetic variation for geographically widespread species than their geographically restricted congeners. But, they also note that there is a wide variance in the range of genetic variation among geographically restricted species, such that some restricted species exhibit as high or higher levels of genetic variation as their widespread congeners, while some widespread species exhibit low levels of genetic variation similar to that found in their restricted congeners (see also Karron 1987b; Karron et al. 1988; Soltis and Soltis 1991; Frankham 1995; Avise 2004).

Concerning historic demographic changes in populations, Karron (1987b; Karron et al. 1988) compared levels of genetic variation (allozyme variants) in geographically restricted and widespread vascular plant species across eleven genera that included *Astragalus* and found that while geographically restricted species tend to have lower levels of genetic variation than widespread species, there are exceptions. Additionally, Travis et al. (1996) examined AFLP variation in populations of the endangered sentry milk vetch (*Astragalus cremnophylax* Barneby var. *cremnophylax*) on the north and south rims of the Grand Canyon, and found that north rim populations possess a level of genetic variation consistent with historical levels, while the south rim populations possess almost no genetic variation. In both of these studies, the authors hypothesized that such heterogeneity in levels of genetic variation among geographically restricted species may be partially attributed to factors affecting reduced range size during the recent past. However, in the case of *A. jaegerianus,* there is no evidence of a historic range reduction (Munz 1941; Barneby 1964; U.S. Fish and Wildlife Service 2001; Charis 2002).

Population genetic theory also predicts that narrow endemic species with small populations and few individuals should exhibit strong population structure due to a higher proportion of genetic variation partitioned among populations (Hamrick and Godt 1989; Hamrick et al. 1991; Frankham et al. 2002; Avise 2004). However, Hamrick and Godt's (1989) review of the allozyme literature revealed that, while some geographically widespread species typically have a greater proportion of genetic variation partitioned within populations, there is no significant difference between geographically widespread and restricted species in how genetic variation is partitioned. In contrast, theory predicts that species with restricted ranges and small populations are expected to have a greater proportion of genetic variation partitioned among populations (Karron 1991; Frankham et al. 2002; Avise 2004).

In this study, we tested the hypotheses that levels of genetic variation in species of restricted ranges and few individuals should be low, with a significant proportion of this variation partitioned among populations. We also examined whether the genetic structure of *Astragalus jaegerianus* correlates with its population geographic distribution. Such an estimate of genetic variation and population structure provides a basis for sustainable management of *Astragalus jaegerianus*.

Methods

The species.—Little is known of the biology of *A. jaegerianus* or its breeding system. It is a cryptic perennial that is generally found associated with a host or nurse shrub that it might use as a trellis (Gibson et al. 1998; Prigge et al. 2000; U.S. Fish and Wildlife Service 2001). It is a member of the Mojave Creosote Bush Scrub within its restricted range, but is only associated with shallow granitic or sandy soils (U.S. Fish and Wildlife Service 2001). Individual plants are often found in small, localized groups of a few individuals with intervening distances (often several hundred meters) of unoccupied, but suitable habitat (Charis 2002). *Astragalus jaegerianus* possesses the typical floral morphology characteristic of the subfamily Papilionoideae (Judd et al. 2002; Tucker 2003). Most species within the Papilionoideae are known to have showy, perfect flowers, which typically attract pollinators (Arroyo 1981). However, breeding systems vary within the Papilionoideae from obligate selfers to obligate outcrossers, including species capable of both (Arroyo 1981; Juan et al. 2004).

Population sampling.—The range of *Astragalus jaegerianus* can be subdivided geographically into five putative distinct populations (Figure 1; Coolgardie, Lane Mountain, Prospectors Wash, Brinkman Wash, and Goldstone). This follows population delineation in the Charis (2002) report and the U.S. Fish and Wildlife Service Recovery Plan (2001), with the exception of the Lane Mountain and Coolgardie populations. In the Charis' (2002) report, these two populations were considered as one (Coolgardie Mesa population), but for this study were split by the Copper City Road for the following reasons. The 2001 survey (Charis 2002) recorded an expanse of unoccupied habitat within the center of the Coolgardie Mesa population, which they attributed to deep alluvial soils but has also been heavily impacted by off-road vehicle users and campers, and residential and agriculture development. Plants recorded in the 2001 survey adjacent to the Copper City Road are approximately one kilometer apart from those on the other side of the road.

Our study began in 2001, one of the driest years on record for the Mojave Desert in California. Because there was essentially no growing season that year, we were only able to collect necrotic tissue. In subsequent years (2002 and 2003), our sampling of *Astragalus jaegerianus* tissue did include green leaflets. Twenty plants were sampled (sampling locations and UTM coordinates are available upon request) within each of the five putative populations. Sampling localities within each population varied from two in the Goldstone population to six in the Coolgardie population, which reflect the distribution of plants. Within each locality, two to 10 plants were collected from 10 to 30 meters apart. Because high molecular weight DNA is necessary for accurate and reproducible AFLP results (Ritland and Ritland 2000; Kingston and Rosel 2004), it was impossible to produce both sequence data and AFLP markers for the same subset of individuals. This was because from the necrotic stem tissue collected at the beginning of our study, we were

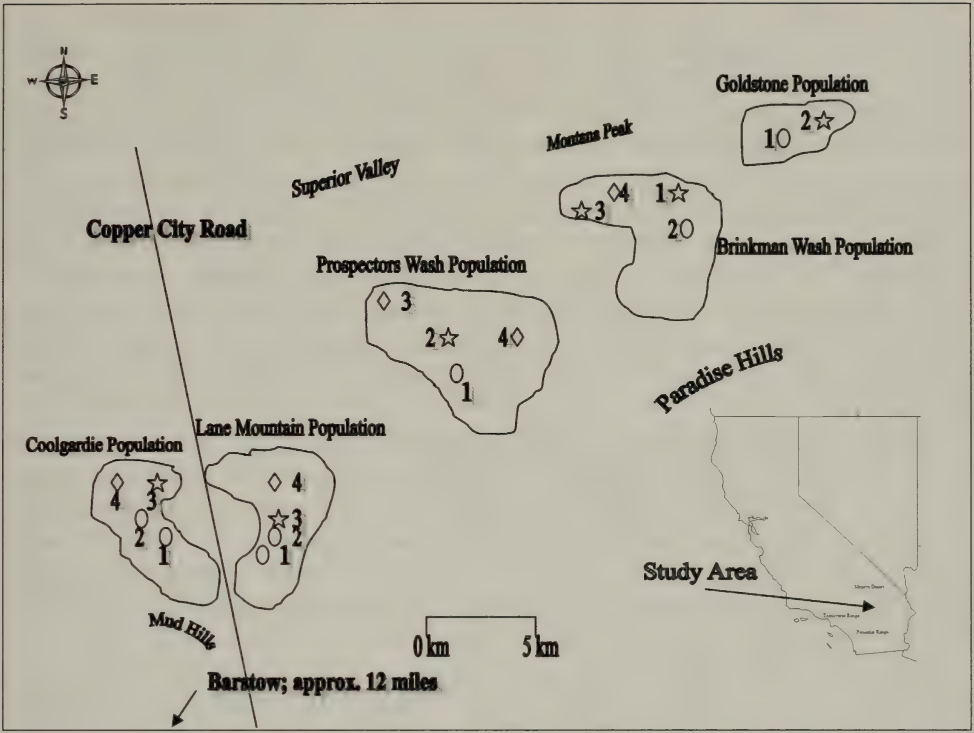

N
W
E
S
Goldstone Population
Montana Peak
Superior Valley
Copper City Road
Brinkman Wash Population
Prospectors Wash Population
Paradise Hills
Lane Mountain Population
Coolgardie Population
Study Area
Mojave Desert
Transverse Range
Peninsular Range
Mud Hills
0 km
5 km
Barstow; approx. 12 miles

Fig. 1. Map of the known distribution of *Astragalus jaegerianus*. The study area is located approximately 12 miles NNE from Barstow, and is bounded on the north and east sides by Ft. Irwin Military Reservation and China Lakes Naval Weapons Center. Extent of the range of *Astragalus jaegerianus* is based on the Charis (2002) report. Plant collecting localities are delineated by: ○-DNA sequenced individuals only, ◇-AFLP Genotyped individuals only, ☆-both DNA sequenced and AFLP Genotyped individuals.

only able to isolate degraded DNA. Although we were able to amplify and sequence our loci of interest from this degraded DNA, the necrotic tissue did not provide sufficient high molecular weight DNA for generation of reliable AFLP markers. Thus, using the earlier collected tissue, nine individuals from each population were DNA sequenced, while later in the study ten individuals from each population were AFLP genotyped using green leaflet tissue collected in 2002–03 that yielded high molecular weight DNA; three individuals each that were collected within the Coolgardie, Brinkman Wash, and Goldstone populations were both DNA sequenced and AFLP genotyped. Two geographically widespread congeners (*Astragalus didymocarpus* H. & A. and *A. layneae* Greene) were also sampled within the range of *A. jaegerianus* (five of each species) for DNA sequencing to test the validity of the monomorphic sequence data for the 45 *A. jaegerianus* individuals.

Genomic DNA isolation.—Three different methods were used for genomic DNA isolation from plant tissue-Qiagen's DNeasy Mini Plant Kit (Chatsworth, California USA), Epicentre's MasterPure^{TM} Plant Leaf DNA Purification Kit (Madison, Wisconsin USA), and a 2X CTAB (hexadecyltrimethylammonium bromide) extraction protocol (Doyle and Doyle 1987). Extracted genomic DNA was quantified using spectrophotometry and visualized for high molecular weight DNA by agarose gel (0.8%) electrophoresis.

PCR amplification and DNA sequencing.—To evaluate intraspecific sequence variation, loci of approximately 1300 total base pairs were selected from both the nuclear genome (nrDNA ITS region) and the chloroplast genome (cpDNA *trnL-F* region, which includes the *trnL* intron and 3′ exon, and the *trnL-F* spacer). To amplify the cpDNA *trnL-F* region, primers B-49317 (5′-CGAAATCGGTAGACGCTACG-3′) and A-50272 (5′-ATTTGAACTGGTGACACGAG-3′) developed by Taberlet et al. (1991) were used. To amplify the nrDNA region, primers ITS-4 (5′-TCCTCCGCTTATTGATATGC-3′) and ITS-5 (5′-GGAAGTAAAAGTCGTAACAAGG-3′) were used (White et al. 1989). In preparation for sequencing, a tailed primer method was utilized to generate amplicons by the Polymerase Chain Reaction (PCR; Mullis et al. 1986). This method employs a two-part primer system with the standard sequencing primers M-13-Forward or M-13-Reverse attached to the 5′ end of each PCR primer in a primer combination.

Amplification was performed using Eppendorf's (Hamburg, Germany) reagents provided with their TAQ polymerase, 1.0–2.0 µl of genomic DNA (a range of 5 to 100 ng/µl), 1.0 µl of each primer at 20 mMol, and 2.5 units of TAQ polymerase, assembled in 50 µl reactions. Cycle parameters were one to two minutes of initial denaturation at 94°C; 30 to 35 cycles of one minute at 94°C for denaturation, one minute at 48°C for annealing the primers, and one minute at 68°C for strand elongation; and five minutes at 68°C for final elongation.

Bi-directional cycle sequencing was accomplished on a Li-Cor, Inc. (Lincoln, Nebraska USA), 4300 DNA Analyzer using IRDyed labeled M-13 forward and reverse sequencing primers for nine individuals from each population with Epicentre's (Madison, Wisconsin USA) SequiTherm Excel^{TM} II DNA Sequencing Kit-LC. Cycle sequencing parameters were an initial denaturation of 95°C for five minutes, and 20 cycles of 95°C for 60 seconds, 54°C for 30 seconds, and 70°C for 60 seconds. Sequences were deposited in the National Institute of Health's GenBank Database (Accession Numbers DQ403838–DQ403850).

Generation of AFLP markers.—AFLP analysis was executed for ten individuals from each population using Li-Cor's, Inc. (Lincoln, Nebraska USA) 4300 DNA Analyzer with their IRDye^{TM} Fluorescent AFLP® Kit for Large Plant Genome Analysis, with several modifications to the kit's protocol. After several trials at various concentrations of genomic DNA, it was found that using approximately 500 ng of genomic DNA resulted in sharp and highly reproducible banding patterns in the gel images. This is similar to what Lanteri et al. (2004) found in their test of reproducibility of bands.

Other modifications included adding 2% deionized formamide to the PCR amplification reaction mixes to sharpen bands and reduce background noise, adjusting the pH of the adaptor ligation mix to pH 8.0 using 0.8 Mol Tris (pH 8.0), and ligating the adaptors at 16°C overnight (Berres 2002).

Sixty-four primer pairs were screened for band clarity and reproducibility, with four primer pairs (Mse1-CAC and EcoR1-ACT, Mse1-CAC and EcoR1-ACC, Mse1-CAC and EcoR1-ACA, Mse1-CAC and EcoR1-AGC) selected that produced clear interpretable and reproducible bands. Each primer pair for all 50 individuals was constructed in a single master mix, with tests for reproducibility of AFLP banding patterns conducted on a subset of the samples. Each individual of the subset was replicated for the four selected primer pairs twice, with a mean scoring error rate of less than one percent (Winfield et al. 1998).

Gels were scored using Li-Cor's, Inc., Saga^{TM} automated AFLP Analysis Software (version 3.1), and verified by eye. Each band position was considered a locus with two alleles, and scored as either present or absent. Only bands occurring between 50 and 500 bases in length were scored, as size homoplasy resulting from co-migrating, non-homologous bands is more frequent among shorter and longer AFLP fragments (Vekemans et al. 2002).

Gene diversity.—Each population contained from two to six sampling localities, but plants from only three sampling localities within each population were used to generate AFLP markers except for one population. The Goldstone population contained two sampling localities, with plants collected from one locality used to generate AFLP markers. Population parameters used to characterize gene diversity included the percentage of polymorphic loci, the number of AFLP phenotypes, and Nei's (1978; 1987) gene diversity. ARLEQUIN 2.0 (Schneider et al. 2000) was used to derive the percentage of polymorphic loci and the number of AFLP genotypes within each population, while POPGENE 1.31 (Yeh et al. 1999), was used to estimate Nei's (1978; 1987) gene diversity across the range of the species and within each population (Gaudeul et al. 2000).

Population genetic structure and gene flow.—The distribution of genetic variation was assessed by a hierarchical analysis of molecular variance (AMOVA, Excoffier et al. 1992) at two levels-within populations and among populations. Wright's (1951) global F_{ST} and population pairwise F_{ST} coefficients were estimated using AMOVA, with significance evaluated by use of a randomization procedure using 1034 randomization replicates and assuming Hardy-Weinberg equilibrium (Gaudeul et al. 2000). The software program Tools for Population Genetics Analysis (TFPGA; Miller 2000) was used to estimate θ_{ST} (Weir and Cockerham 1984; Weir 1996), while POPGENE 1.31 was used to estimate Neiv's G_{ST} (Nei 1987); both are analogs to Wright's (1951) F_{ST}. TFPGA was also used to calculate Nei's unbiased (1978) genetic distances among the five populations, and to construct a population UPGMA cluster phenogram based on the population pairwise comparisons of the genetic distances. The constructed tree was bootstrapped (1000 permutations) to determine support for each node.

Population genetic structure was tested by constructing an UPGMA phenogram to portray genetic relationships among individuals using the software package PAUP 4.0d64 (Swofford 1998). Principle Coordinates Analysis (PCoA) using AFLP phenotypes was performed using the R Package, version 4.0d6 (Casgrain and Legendre 2001) that allows the positioning of objects in a two-dimensional reduced space that preserves their relationships.

To test whether population structure follows an isolation by distance model, two distance matrices were compared (Mantel test; Mantel 1967) using the R Package, version 4.0d6 (Casgrain and Legendre 2001), with significance (r_M) tested using 9999 permutations. In this case, we tested for correlation between Nei's genetic distances and geographic distances among all five populations. Geographic distances between populations were determined by measuring a straight line between approximate central points within each population (Legendre and Legendre 1998).

Tests for association between population density and gene diversity, population area and gene diversity, and population size and gene diversity were performed in SPSS (Windows version 12.0, SPSS Inc., Chicago, Illinois USA). Population demographic values are from Charis (2002) (see Table 1). For all tests of association performed in

Table 1. Population demographics and gene diversity statistics. Descriptive statistics for genetic variability include the proportion of polymorphic loci (P), the number of AFLP phenotypes for each population with the number of individual plants sampled in parentheses, mean distance between sampling localities within each population, and Nei's (1978) index of gene diversity.

Population	Sample Size	Pop.[a] Size	Pop.[b] Range	Pop.[c] Density	P(%)	No. of AFLP phenotypes	MSD[d] ± SE	Gene Diversity Mean ± std. dev.
Lane Mountain	10	1027[e]	4911	0.21	55.8	10 (10)	0.973 ± 0.133	0.1905 ± 0.2008
Coolgardie	10	987[e]	4867	0.20	55.5	10 (10)	1.041 ± 0.087	0.1910 ± 0.2012
Prospectors Wash	10	1667	4794	0.38	68.3	10 (10)	3.438 ± 0.453	0.2316 ± 0.2014
Brinkman Wash	9	1487	5497	0.27	65.5	9 (9)	2.815 ± 0.105	0.2283 ± 0.2036
Goldstone	10	555	1283	0.43	70.0	10 (10)	0.820 ± 0.000	0.2505 ± 0.2004

[a] Population sizes are taken from the Charis (2002) report.

[b] Total acreage in each population polygon (Charis 2002).

[c] Plants per acre.

[d] Mean Sampling Distance (km) was derived by computing the mean distance between each population's sampling points, and then computing the mean of means with standard error for each population.

[e] The Charis (2002) report considered the Lane Mountain and Coolgardie populations as one population (Coolgardie Mesa). Population size estimates were derived by proportioning the Coolgardie Mesa population size estimate between the proportions of acreage determined by Charis (2002) on either side of the Copper City Road.

SPSS, Pearson's product moment correlation coefficient (r) was derived at a significance level of $\alpha = 0.05$.

ARLEQUIN 2.0 (Schneider et al. 2000) was used to estimate gene flow among the five populations. Gene flow (Nm; $F_{ST} = 1/(4\,Nm + 1)$) was derived indirectly using the estimates of population pairwise F_{ST} values (Neigel 1997; Wright 1951), also derived in ARLEQUIN 2.0. A Mantel test for correlation (Mantel 1967) between Nm and geographic distances was performed using the R Package, version 4.0d6 (Casgrain and Legendre 2001).

Results

DNA sequencing.—The nrDNA ITS region and the cpDNA *trnL-F* region were sequenced for nine individual plants from each population (n = 45). The cpDNA *trnL-F* sequence produced an amplicon of 699 nucleotide bases, while the nrDNA ITS sequence produced an amplicon of 595 nucleotide bases. Sequences from each region were verified, with boundary determination, by comparison with retrieved sequence data for *Astragalus* on the National Institute of Health's GenBank Database (<http://www.ncbi.nlm.nih.gov/Genbank/>). Alignments of the cpDNA and nrDNA sequences derived from the 45 *A. jaegerianus* individuals failed to reveal any sequence variation within both regions.

On the other hand, the nrDNA ITS sequences for five *Astragalus didymocarpus* individuals revealed nine nucleotide polymorphisms out of 595 bases (1.5%, three genotypes), while DNA sequences for three *A. layneae* individuals revealed two nucleotide polymorphisms out of 595 bases (0.34%, three genotypes). For sequences of the cpDNA *trnL-F* region, three of five *A. didymocarpus* individuals possessed two indels (one 7 bases in length and the other one base only) along with three single nucleotide polymorphisms (substitutions) out of 699 bases (0.43%, three haplotypes). Three

Table 2. Analysis of Molecular Variance (AMOVA) for two hierarchical levels (among populations and within populations).

Source of variation	d.f.	Sum of squares	Variance components	Percentage of variation
Among populations	4	343.516	5.26513	13.31
Within populations	44	1509.300	34.30227	86.69
Total	48	1852.816	39.56741	

$F_{ST} = 0.133$, $p < 0.00001$

individuals of *A. layneae* were sequenced for the same region with two nucleotide polymorphisms out of 699 bases (0.29%, two haplotypes) and no indels. While the sequence data characterized the 45 individuals of *Astragalus jaegerianus* as monomorphic, the variable sequence data for individuals of *Astragalus didymocarpus* and *A. layneae*, combined with the demonstrated utility of the examined loci, suggests that this narrow endemic may be relatively depaurate of genetic variation compared to its congeners.

AFLP markers.—AFLP generated a total of 360 markers from the four primer pairs for 49 individuals (10 from each population, with the exception of the Brinkman Wash population, wherein one individual was omitted from the study due to lack of amplification in the selective amplification step). Of the 360 AFLP bands scored, 290 (80.5%) were polymorphic. The four AFLP binary data sets were combined after removal of the monomorphic bands to make a single data set for further analyses (Despres et al. 2003; Coart et al. 2005; Muellner et al. 2005).

Gene diversity.—The AFLP data reveals each *A. jaegerianus* individual sampled as a unique multi-locus genotype, which is contrary to the monomorphism found in the chloroplast and nuclear DNA sequences. The proportion of polymorphic loci found in each population ranged from a low of 55.5% in the Coolgardie population to a high of 70.0% in the Goldstone population (Table 1). Mean gene diversity (Nei 1987) within the range of the species was estimated at 0.2660 (SD = 0.1603). When estimated separately for the five populations, mean gene diversity ranged from a low of 0.1905 (SD = 0.2008) for the Lane Mountain population in the southwest to a high of 0.2505 (SD = 0.2004) for the Goldstone population in the northeast (Table 1).

Population genetic structure and gene flow.—Analysis of molecular variance (AMOVA) revealed that 13% of the observed genetic variation was partitioned among the five populations and 87% partitioned within populations (Table 2). Global F_{ST} (Wright, 1951) obtained by AMOVA revealed significant differentiation among the five populations ($F_{ST} = 0.133$, $p < 0.01$). Analogs of F_{ST} were similar but slightly higher (estimated $\theta_{ST} = 0.174$ and $G_{ST} = 0.180$). F_{ST} indices obtained for pairwise comparisons among the five populations ranged from a low of 0.051 (for Prospectors Wash/Brinkman Wash populations) to a high of 0.232 (for Lane Mountain/Goldstone populations), with significant differentiation observed for all population pairwise comparisons (Table 3).

Estimated unbiased genetic distances (Nei 1978; 1987) of pairwise comparisons among the five populations and geographic distances between populations are displayed in Table 4. In a Mantel test for isolation by distance, a significant positive correlation ($r_M = 0.823$, $p < 0.05$) was found between the population pairwise estimates of unbiased genetic distances and geographic distances (5.00 km to 27.50 km) separating each population. The population UPGMA dendrogram (Figure 2) based on Nei's unbiased genetic distances also supports this geographic structure. Both the unrooted UPGMA

Table 3. Population pairwise F_{ST} indices[a] derived in AMOVA below the diagonal and estimated numbers of migrants (m) exchanged among populations per generation above the diagonal [$F_{ST} = 1/(4\ Nm + 1)$].

Population	Ln. Mtn.	Coolg.	Prosp. Wash	Brinkm. Wash	Goldstone
Lane Mtn.	****	3.352	2.135	1.314	0.826
Coolgardie	0.06941	****	3.233	1.678	0.918
Prospectors W.	0.10482	0.07178	****	4.650	1.635
Brinkman W.	0.15990	0.12965	0.05102	****	1.977
Goldstone	0.23233	0.21408	0.13266	0.11228	****

[a] $p<0.01$ for all population pairwise F_{ST} indices (1024 permutations)

dendrogram of individuals (Figure 3) and the first and second principal coordinates of the PCoA cluster plot (accounting for 10.0 and 5.3% of the variance, respectively; Figure 4) illustrate this significant population structure in different ways. Within both figures, individuals tend to cluster with other individuals collected within the same population, with a few exceptions. Specifically, individuals collected within the Lane Mountain and Coolgardie populations cluster together in both the PCoA cluster plot and UPGMA dendrogram. This suggests a close relatedness between individuals collected from both populations, which is consistent with both populations having the lowest pairwise genetic distance (0.0381; Table 4). Even so, the populations show significant genetic differentiation (population pairwise F_{ST} coefficient 0.069, $p < 0.001$; Table 3), which supports delineating two populations in the southern end of the species range, rather than one population as was done in the Charis (2002) report.

There is a significant positive correlation between population density and gene diversity ($r = 0.931$, $p < 0.05$), but not between gene diversity and population size ($r = -0.022$, $p > 0.05$) or population area ($r = -0.616$, $p > 0.05$). This is contrary to predictions, as population area or population size is typically positively linked to the level of gene diversity in a population (Despres et al. 2002; Godt et al. 1996; Godt et al. 2005). For instance, individuals within the Goldstone population were spread over a relatively large proportion of the PCoA two-dimensional coordinate space (Figure 4) and had the highest gene diversity (0.2505; Table 1); yet, the Goldstone population is the smallest of the five populations-both in census numbers (555 individuals) and in area (1283 acres; Charis 2002). This suggests that in this case the level of gene diversity a population may possess is best predicted by plant density.

Estimated migration rates per generation (Nm; Table 3) ranged from a high of 4.65 between Prospectors Wash/Brinkman Wash populations to a low of 0.83 between Lane Mountain/Goldstone populations. The estimated migration rates were higher between

Table 4. Estimates of Nei's (1978) unbiased genetic distances between populations are displayed on the lower diagonal, and geographical distances[a] between populations are displayed on the upper diagonal.

Population	Lane Mtn.	Coolgardie	Prospectors W.	Brinkman W.	Goldstone
Lane Mtn.	*****	5.00	10.50	18.00	23.00
Coolgardie	0.0381	*****	14.50	23.00	27.50
Prospectors W.	0.0537	0.0501	*****	9.50	14.50
Brinkman W.	0.0687	0.0680	0.0420	*****	5.50
Goldstone	0.1004	0.0926	0.0639	0.0619	*****

[a] Kilometers

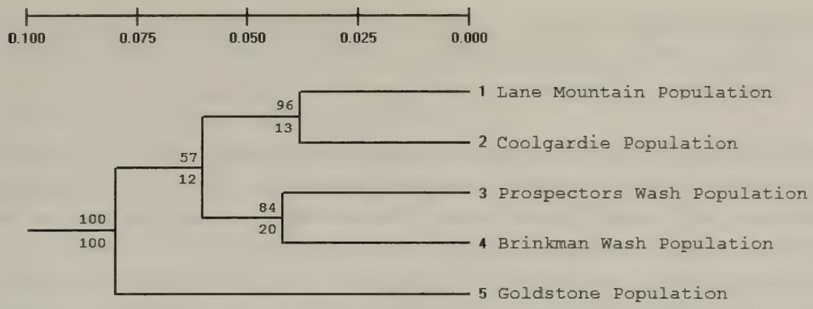

0.100
0.075
0.050
0.025
0.000
96
13
57
12
84
20
100
100
1 Lane Mountain Population
2 Coolgardie Population
3 Prospectors Wash Population
4 Brinkman Wash Population
5 Goldstone Population

Fig. 2. UPGMA cluster diagram derived from estimates of Nei's (1978) unbiased genetic distances among populations of *Astragalus jaegerianus*. Values above the nodes are bootstrap values supporting the node (1000 permutations), and values below the node are the proportion of loci supporting the node.

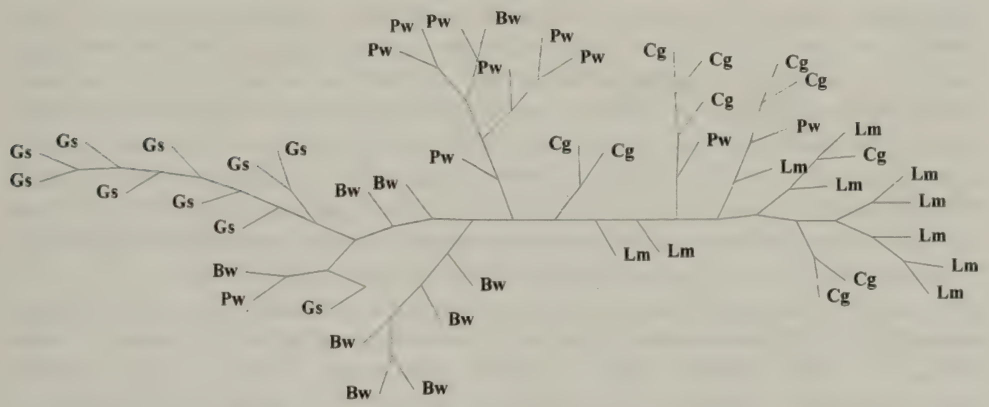

Gs
Pw
Bw
Cg
Lm

Fig. 3. Unrooted UPGMA dendrogram displaying genetic distances among the 49 individual *Astragalus jaegerianus* AFLP phenotypes. Population designations are Lm for Lane Mountain, Cg for Coolgardie, Ps for Prospectors Wash, Bw for Brinkman Wash, and Gs for Goldstone.

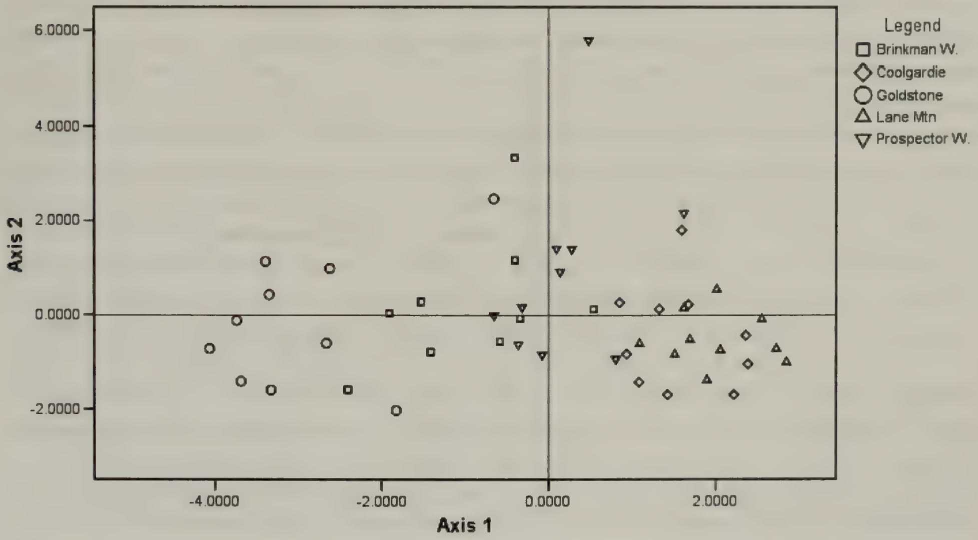


Fig. 4. PCoA cluster plot of the first and second principal coordinates based on the 49 individual *Astragalus jaegerianus* AFLP phenotypes.

adjacent populations than between populations separated by one or more populations and are negatively correlated with geographic distance ($r_M = -0.671$, $p < 0.05$).

Discussion

Gene diversity.—The objective of this study was to investigate the level of genetic variation and it's partitioning for *Astragalus jaegerianus.* We hypothesized that this narrow endemic, with small populations and few individuals, would be characterized with low genetic variation partitioned at the population level. Both data sets (DNA sequences and AFLP markers) gave seemingly incongruent results. No genetic variation was observed in the examined sequences of the chloroplast and nuclear genomes, while AFLP analysis of the entire genome (see Vos et al. 1995; Mueller and Wolfenbarger 1999) revealed substantial genetic variation and population structure. This lack of DNA sequence variation may be due to *A. jaegerianus*' small population sizes and restricted geographical range, or because of unknown historical factors (Karron et al. 1988; Schmidt and Jensen 2000). In comparison, sequence data from *Astragalus didymocarpus* and *A. laynae* did reveal substantial DNA sequence variation for both the same chloroplast and nuclear loci. These same loci have also been utilized to characterize intraspecific genetic variation within other plant taxa (Terry et al. 2000; Chiang et al. 2004; Dobes et al. 2004; Franzke et al. 2004; Lihova et al. 2004; Ruggiero and Procaccini 2004; but see Shaw et al. 2005). Therefore, when only DNA sequence variation at these loci is considered, this narrow endemic appears genetically depauperate, and suggests that *A. jaegerianus*' populations have recently descended from a few individuals.

In contrast, the genome-wide survey using AFLP markers revealed a level of gene diversity for *A. jaegerianus* that is similar to levels of gene diversity observed in other studies that used AFLP markers to characterize gene diversity in geographically widespread species. Despres et al. (2002) characterized the levels and distribution of genetic variation for the widespread European globeflower (*Trollius europaeus* L.) and found that levels of genetic variation among the three regions ranged from 0.158 to 0.229, which is also similar to the level of gene diversity (0.243) that Tang et al. (2003) reported in their study of the geographically widespread *Hibiscus tiliaceus* L. (Malvaceae). The level of gene diversity for geographically restricted species is different. Juan et al. (2004), when characterizing the levels of AFLP gene diversity for the endangered *Medicago citrine* (Font Quer) Greuter (Fabaceae, Papilionoideae), found that gene diversity ranged from 0.035 to 0.143, a ~13 to 55% reduction from those gene diversity indices reported here for *A. jaegerianus.* Travis et al. (1996) report an extremely low level of gene diversity (0.0177 and 0.0373) for the south rim populations of the critically endangered *Astragalus cremnophylax* var. *cremnophylax*. The patterns of AFLP gene diversities reported for geographically restricted species (Travis et al. 1996; Juan et al. 2004) and geographically widespread species (Despres et al. 2002; Tang et al. 2003) are similar to patterns of gene diversity for restricted and widespread species reported in Hamrick's et al. (1991) review of the allozyme literature. In their review, they note a pattern of gene diversity that averages around 0.202 for widespread species and around 0.09 for narrow endemics. The level of gene diversity for *A. jaegerianus* is higher than expected when compared to these patterns (Karron 1991), as population genetic theory predicts that species with restricted ranges and few individuals would have low levels of genetic variation (Hamrick & Godt 1989; Hamrick et al. 1991; Soltis and Soltis 1991; Ellstrand and Elam 1993; Godt et al. 1996; Gitzendanner and Soltis 2000; Frankham et al. 2002; Avise 2004). Although comparing patterns of gene diversity generated by either allozyme data (co-dominant markers) or AFLP data (dominant markers) may not be equitable, it does provide a comparison for putting the level of gene diversity found in *A. jaegerianus* in context with gene diversity patterns reported for other plant taxa using different molecular markers (Alexander et al. 2004; Nybom 2004).

This high level of genetic diversity for this narrow endemic, with small populations and few individuals, suggests that *Astragalus jaegerianus* has undergone a recent population contraction or is undergoing population contraction, such that the populations may have had a recent common history (Schmidt and Jensen 2000; Ellis et al. 2006; Vilatersana et al. 2007). Similar high levels of gene diversity for narrow endemic plants have been observed previously (Karron 1987b; Alexander et al. 2004; Vilatersana et al. 2007). Karron (1987b; Karron et al. 1988) compared levels of allozyme genetic variation in both restricted and geographic widespread plant congeners including four species of *Astragalus*, and observed that there is considerable variance in levels of gene diversity reported for rare species. In a subsequent review, Karron (1991) observed that in some cases the extent of geographic range could be a poor predictor of the level of genetic variation a species may possess (see also Soltis and Soltis 1991). Alexander et al. (2004) reported a level of population gene diversity (ranging from 0.14 to 0.18) for the narrow endemic *Astragalus oniciformis* Barneby that is a little lower but similar to what was found for *A. jaegerianus* (Table 1). Vilatersana et al. (2007) also reports high gene diversity (0.17) for the endangered *Femeniasia balearica* (J. J. Rodr.) Susanna-a narrow endemic confined to the Balearic Islands of Spain. Both Alexander et al. (2004) and Vilatersana et al. (2007) attributed their high gene diversity to either recent change in population demographics, reduced effects of genetic drift on populations of long-lived woody species with overlapping generations, or groups of putative identified populations acting as a population. Other factors influencing the observed patterns of genetic variation in these geographically restricted species may include differences in the present and historic range of a species, recent bottlenecks and founder events, and repeated cycles of bottlenecks and range expansions (Karron 1991; Schmidt and Jensen 2000; Frankham et al. 2002; Avise 2004). However in our case, we have no information regarding these factors for *A. jaegerianus*, except that it has been restricted in range and population size since its discovery in 1938 (Munz 1941; Barneby 1964).

Typically within plant taxa there is a positive correlation between geographic range and gene diversity or population size and gene diversity (Hamrick & Godt 1989; Ellstrand & Elam 1993; Godt et al. 1996; Fischer & Matthies 1998; Gram & Sork 1999; Gaudeul et al. 2000; Lu et al. 2005), both of which are commensurate with population genetic theory that small populations cannot maintain high levels of gene diversity (reviewed in Soltis & Soltis 1991). Our findings demonstrate that population density ($r = 0.931$, $p < 0.05$), rather than population size ($r = -0.022$, $p > 0.05$) or population area ($r = -0.616$, $p > 0.05$), is a better predictor for the levels of genetic variation possessed by any of the five populations of *Astragalus jaegerianus*. This association between population density and gene diversity suggests a reproductive strategy for *A. jaegerianus* (discussed below).

Population genetic structure and gene flow.—The partitioning of genetic variation among populations by *Astragalus jaegerianus* is noteworthy, as all five populations are small, both in geographic area and census size; a pattern that led us to predict that this narrowly endemic species would possess low genetic variation partitioned primarily at the population level (Hamrick and Godt 1989; Hamrick et al. 1991; Soltis and Soltis 1991; Ellstrand and Elam 1993). The proportion (13%) of genetic variation partitioned among populations of *A. jaegerianus* is less than the amount of genetic variation partitioned among populations of geographically restricted species, and more similar to patterns reported for geographically widespread species (Hamrick et al. 1991; Soltis and Soltis 1991). In AFLP studies in particular, Travis et al. (1996) reported that 73% of the observed genetic variation for the endangered *Astragalus cremnophylax* var. *cremnophylax* was partitioned among populations, while Juan et al. (2004) found 44% of the AFLP variation reported for the endangered *Medicago citrine* partitioned among populations. A specific example of genetic variation (AFLP) partitioning by a geographically widespread species is the European globeflower, wherein Despres et al. (2002) found this species partitions its genetic variation at 16% among populations across the Alps, 31% among populations throughout the Pyrenees, and 26% in populations across the Fennoscandia region; values, although higher, are more within the range of that observed for *A. jaegerianus* (13%). This suggests, along with gene diversity indices, that *A. jaegerianus* and its populations may be experiencing range and/or population contractions (Schmidt and Jensen 2000; Ellis et al. 2006).

The genetic structure of *Astragalus jaegerianus* corresponds with the species' spatial arrangement of populations in the field, which follows a near linear pattern from southwest to northeast (Figure 1). There is a linear trend from the southwest to the northeast for increasing genetic distances, and increasing population differentiation; a geographical pattern that is unlikely a result of chance or random processes. While the Mantel test of correlation between genetic distance and geographic distance matrices supports an isolation by distance model for the species, the linear patterns of population pairwise comparisons of F_{ST} indices (Table 3) and genetic distances (Table 4) also suggest that the geographic arrangement of the populations follows the one-dimensional stepping stone model, rather than the island model for gene flow (see the review in Halliburton 2004). This spatial arrangement of the populations on the landscape combined with the patterns of genetic variation within and among populations and estimates of gene flow among populations (below) all provide insight into the reproductive biology of *Astragalus jaegerianus*.

The indirect estimates of gene flow partially explain population genetic structure and population levels of genetic variation observed for *Astragalus jaegerianus* (Wright, 1951; reviewed by Slatkin 1985; but see Bossart and Powell 1998; Whitlock & McCauley 1999). Typically, a higher proportion of genetic variation is partitioned within populations of geographically widespread and long-lived species-species often with the potential for long-range gene flow; whereas in species with restricted ranges, small populations, and limited gene flow, a higher proportion of the genetic variation is partitioned among populations (Hamrick and Godt 1989; Karron 1991; Richards et al. 1999). It has already been shown that *A. jaegerianus* possesses a level of gene diversity and population genetic structure comparable to patterns observed in geographically widespread species, thus the estimated high gene flow (*Nm*; Table 3) for *A. jaegerianus* is not unexpected and is comparable to other studies with similar population genetics (Despres et al. 2002; Tang et al. 2003; Alexander et al. 2004).

The analyses support a mixed breeding strategy of outcrossing and selfing that suggests pollinator-mediated gene flow. We hypothesize that within areas of high plant density *A. jaegerianus* may rely on outcrossing facilitated by one or more pollinators (Levin & Kerster 1969a; Levin & Kerster 1969b; Ellstrand et al. 1978; Van Treuren et al. 1993; Franceschinelli and Bawa 2000). This is based on floral morphology and the association of population gene diversity indices scaling with population density, as well as the global and population pairwise F_{ST} coefficients (Table 2 and 3). As such, we predict greater gene diversity within higher density populations, with less genetic differentiation among adjacent populations than more distant populations due to gene flow. Regarding the distribution of genetic variation among plants with mixed mating systems, Loveless and Hamrick (1984) and Hamrick and Godt (1989) suggest that an allozyme-generated F_{ST} coefficient of ~0.2 indicates outcrossing is predominantly occurring, while a F_{ST} coefficient of ~0.5 indicates selfing is predominantly occurring. Additionally, gene flow mediated by pollinators among most members of the Papilionoideae is supported by showy, perfect flowers, which typically attract pollinators (Arroyo 1981). However, breeding systems vary within the Papilionoideae from obligate selfers (geitonogamy and autogamy) to obligate outcrossers (cross pollination between flowers from different plants), with some Papilionoideae taxa, including some *Astragalus* species, capable of both (Karron 1987a; Arroyo 1981; Juan et al. 2004). Moreover, geographic distance and population density have been shown to interact to affect the rate of gene flow between populations (Bateman 1947; Karron et al. 1995; Roll et al. 1997; Richards et al. 1999). Roll et al. (1997) experimentally demonstrated that pollinator visitation at flowers increases as floral density increases within a population. For populations with high floral densities, pollinator visits are high but mean flight distances are shorter, while in low-density populations pollinator visits are low with longer mean flights distances (Roll et al. 1997; Richards et al. 1999). Thus, in high-density populations, plants receive more pollinator visits than plants in lower density populations, which effectively increase the effective local pollen pool among plants, and maintains higher levels of within-population gene diversity. On the other hand, in low-density populations plants receive fewer pollinator visits, which results in a reduced effective pollen pool and a greater reliance on self-fertilization for seed production, both of which can decrease within-population gene diversity (Proctor et al. 1996). Of interest is that gene flow is likely to be higher among low-density populations due to fewer within-population flower visits and increased pollinator flight distances (Handel 1983). However, if selfing increases in low-density populations, we predict lower within-population gene diversity. These are the patterns we observed.

Summary.—Astragalus jaegerianus possesses a high level of gene diversity as estimated by AFLP that is predominantly partitioned within populations; a scenario comparable to patterns of gene diversity observed in geographically widespread species. The data indicate that there is low but significant genetic structure, with each population genetically divergent from the others. While population density partially predicts the level of genetic variation within populations, genetic structure among populations is explained by geographic distances, suggesting a stepping-stone model for gene flow. These results support *A. jaegerianus* as a facultative outcrosser with pollinator-mediated gene flow. The association of gene diversity and population density is also congruent with both outcrossing and selfing, with less dense populations having a higher proportion of selfers. In the case of *Astragalus jaegerianus*, this also explains why gene diversity is not correlated with population size. This is noteworthy, as normally population size and gene diversity are linked (Fischer & Matthies 1998; Gaudeul et al. 2000; Despres et al. 2002).

Conservation implications and recommendations.—The ultimate goal of conservation biology is to conserve species and their evolutionary potentials. The monomorphic DNA sequence data, considered alone, suggest that an estimated effective population size for *Astragalus jaegerianus* may be far below the 2001 census population size of approximately 5,700 individuals (Frankham et al. 2002; Halliburton 2004). This suggests management efforts should focus on conserving as many individuals as possible across the range of the species to capture any variation present in other gene loci.

On the other hand, the AFLP analyses of the levels and distribution of genome-wide variation indicates that *A. jaegerianus* possesses a level of gene diversity and population structure comparable with geographically widespread species; a scenario that suggests this species has undergone, or is undergoing, population contraction. Each population may contain some unique genetic contribution that is locally adapted to environmental conditions, and, since gene flow appears high among adjacent populations, augmentation for any of the five populations appears unwarranted at this time (Ellstrand and Elam 1993). Goldstone, the smallest of the five populations, contains the highest gene diversity. However, because of its small size, both in acreage and census numbers, it is the most at risk of the five populations from habitat loss and degradation.

The hypothesis of *A. jaegerianus* being a facultative outcrosser should be experimentally tested in the field. In addition, pollinators of *A. jaegerianus* must be identified, and their reproductive biology considered during conservation planning. One or more factors of the reproductive biology of pollinators may be a limiting factor for the conservation of *A. jaegerianus*, and maintenance of the present levels and partitioning of genetic variation (Karron 1989).

Lastly, this study provides important baseline data for monitoring trends in the population genetics of *Astragalus jaegerianus*. Since *A. jaegerianus*' level of genetic variation and its partitioning among populations is dependent on population size and density, fluctuations in either of these parameters may put this species at risk. Monitoring efforts, therefore, should include regular plant surveys to estimate population sizes and plant densities, as well as periodic surveys using molecular assays to assess changes in levels of genetic variation and population genetic structure. Future population genetic work on *A. jaegerianus* should include a comparison of the population genetics between the three species of *Astragalus* (*A. jaegerianus*, *A. didymocarpus*, and *A. Laynae*) and testing the validity of the five putative populations, with a fine-scale study utilizing a larger sample size.

Acknowledgments

The authors thank James Ferrari for helpful comments on the manuscript and his invaluable advice and guidance during this study; two anonymous reviewers for their constructive comments that improved an earlier draft of the manuscript; Mickey Quillman, Directorate of Public Works at Ft. Irwin, and Mark Hessing, Charis Professional Services Corporation, for providing topographic maps and GPS locations of plants; and Keri Maher, Mark Hessing and his staff, and Micaele Maddison and Elizabeth Delk for assisting with the location of plants in the field. Funding was provided by the Department of the Army, Ft. Irwin (Contract # DACW09-02-P-0060) and the National Science Foundation (MRI Grant DBI # 0321209). Plant tissue was collected under the authority of U.S. Fish and Wildlife Service Permit FWSVFWO-8, FWSVFWO-10, and FWSVFWO-11; and letters of authorization from the Department of the Army, Ft. Irwin National Training Center, and the U.S. Bureau of Land Management.

Literature Cited

Ackerly, D.D. 2003. Community assembly, niche conservatism, and adaptive evolution in changing environments. International Journal of Plant Sciences, 164:S165–S184.

Alexander, J.A., A. Liston, and S.J. Popovich. 2004. Genetic diversity of the narrow endemic *Astragalus oniciformis* (Fabaceae). American Journal of Botany, 91:2004–2012.

Arroyo, M.T.K. 1981. Breeding systems and pollination biology in Leguminosae. In (R.M. Polhill and P.H. Raven, eds.). Advances in Legume Systematics, Part 2 (Proceedings of the International Legume Conference, 1978), Pp. 723–769, Royal Botanical Gardens, Kew, United Kingdom.

Avise, J.C. 2004. Molecular Markers, Natural History and Evolution, 2nd ed. Chapman & Hall, New York, New York, USA. 684 pp.

Barneby, R.C. 1964. Atlas of North American *Astragalus*, Part 1, the Phacoid and Homaloboid Astragali. Memoirs of the New York Botanical Garden, Volume 13.

Barrett, S.C.H. and J.R. Kohn. 1991. Genetic and evolutionary consequences of small population size in plants: implications for conservation. In (D.A. Falk and K.E. Holsinger, eds.). Genetics and Conservation of Rare Plants, Pp. 1–30, Oxford University Press, New York, New York, USA. xviii+283 pp.

Bateman, A.J. 1947. Contamination of seed crops. I. Insect pollination. Journal of Genetics, 48:257–275.

Berres, M.E. 2002. Studies in Avian Population Genetic Structure. Website http://ravel.zoology.wisc.edu/sgaap/ [Accessed 5 July 2004].

Bossart, J.L. and D.P. Prowell. 1998. Genetic estimates of population structure and gene flow: limitation, lessons, and new directions. Trends Ecology and Evolution, 13:202–206.

Casgrain, P. and P. Legendre. 2001. The R-Package for Multivariate and Spatial Analysis, version 4.0d6-users manual. Departement de Sciences Biologiques. Universite de Montreal, Website http://www.fas.umontreal.ca/BIOL/legendre/ [Accessed 15 January 2005]

Chiang, Y.C., B.A. Schaal, Y.J. Ge, and T.Y. Chiang. 2004. Range expansion leading to departures from neutrality in the nonsymbiotic hemoglobin gene and the cpDNA *trnL-trnF* intergenic spacer in *Trema dielsiana* (Ulmaceae). Molecular Phylogenetics and Evolution, 31:929–942.

Charis Professional Services Corporation. 2002. Distribution and abundance of Lane Mountain Milkvetch (*Astragalus jaegerianus*). Report of spring–summer 2001 survey. Unpublished report prepared for the U.S. Army National training Center, Fort Irwin, California, USA. Contract No. GS09K99BHD0007.

Clegg, M.T. 1990. Molecular diversity in plant populations. In (H.D. Brown, M.T. Clegg, A.L. Kahler, and B.S. Weir, eds.). Plant Population Genetics, Breeding, and Genetic Resources, Pp. 98–115, Sinauer Associates, Inc., Sunderland, Massachusetts, USA. xii+449 pp.

Coart, E., S.V. Glabeke, R.J. Petit, E.V. Bockstaele, and I. Roldan-Ruiz. 2005. Range wide versus local patterns of genetic diversity in hornbeam (*Carpinus betulus* L.). Conservation Genetics, 6:259–273.

Cole, C.T. 2003. Genetic variation in rare and common plants. Annual Review of Ecology, Evolution, and Systematics, 34:213–237.

Conner, J.K. and D.L. Hartl. 2004. A Primer of Ecological Genetics. Sinauer Associates, Inc., Sunderland, Massachusetts, USA. xv+304 pp.

Despres, L., S. Loriot, and M. Gaudeul. 2002. Geographic pattern of genetic variation in the European globeflower *Trollius europaeus* L. (Ranunculaceae) inferred from amplified fragment length polymorphism markers. Molecular Ecology, 11:2337–2347.

———, L. Gielly, B. Redoutet, and P. Taberlet. 2003. Using AFLP to resolve phylogenetic relationships in a morphologically diversified plant species complex when nuclear and chloroplast sequences fail to reveal variability. Molecular Phylogenetics and Evolution, 27:185–196.

Dobes, C.H., T. Mitchell-Olds, and M.A. Koch. 2004. Extensive chloroplast haplotype variation indicates Pleistocene hybridization and radiation of North American *Arabis drummondii*, *A.* x *divaricarpa*, and *A. holboellii* (Brassicaceae). Molecular Ecology, 13:349–370.

Doyle, J.J. and J.L. Doyle. 1987. A rapid DNA isolation procedure for small quantities of fresh leaf tissue. Phytochemical Bulletin, 19:11–15.

Ellis, J.R., C.H. Pashley, J.M. Burke, and D.E. McCauley. 2006. High genetic diversity in a rare and endangered sunflower as compared to a common congener. Molecular Ecology, 15:2345–2355.

Ellstrand, N.C. and D.R. Elam. 1993. Population genetic consequences of small population size: implications for plant conservation. Annual Review of Ecology and Systematics, 24:217–242.

———, A.M. Torres, and D.A. Levin. 1978. Density and the rate of apparent outcrossing in *Helianthus annuus* (Asteraceae). Systematic Botany, 3:403–407.

Epperson, B.K. 1990. Spatial patterns of genetic variation within plant populations. In (H.D. Brown, M.T. Clegg, A.L. Kahler, and B.S. Weir, eds.). Plant Population Genetics, Breeding, and Genetic Resources, Pp. 229–253, Sinauer Associates, Inc., Sunderland, Massachusetts, USA. xii+449 pp.

Excoffier, L., P.E. Smouse, and J.M. Quattro. 1992. Analysis of molecular variance inferred from metric distances among DNA haplotypes: application to human mitochondrial DNA restriction data. Genetics, 131:479–491.

Fischer, M. and D. Matthies. 1998. RAPD variation in relation to population size and plant fitness in the rare *Gentianella germanica* (Gentianaceae). American Journal of Botany, 85:811–819.

Franceschinelli, E.V. and K.S. Bawa. 2000. The effect of ecological factors on the mating system of a South American shrub species (*Helicteres brevispira*). Heredity, 84:116–123.

Frankham, R. 1995. Conservation Genetics. Annual Review of Genetics, 29:305–327.

———, J.D. Ballou, and D.A. Briscoe. 2002. Introduction to Conservation Genetics. Cambridge University Press, Cambridge, United Kingdom. xxi+617 pp.

Franzke, A., H. Hurka, D. Janssen, B. Neuffer, N. Friesen, M. Markov, and K. Mummenhoff. 2004. Molecular signals for late Tertiary/Early Quaternary range splits of an Eurasian steppe plant: *Clausia aprica* (Brassicaceae). Molecular Ecology, 13:2789–2795.

Gaudeul, M., P. Taberlet, and I. Till-Bottraud. 2000. Genetic diversity in an endangered alpine plant, *Eryngium alpinum* L. (Apiaceae), inferred from amplified fragment length polymorphism markers. Molecular. Ecology, 9:1625–1637.

Gibson, A.C., M.R. Sharifi, and P.W. Rundel. 1998. Ecophysiological observations on Lane Mountain milkvetch, *Astragalus jaegerianus* (Fabaceae), a proposed endangered species of the Mojave Desert. Alsio, 17:77–82.

Gitzendanner, M.A. and P.S. Soltis. 2000. Patterns of genetic variation in rare and widespread plant congeners. American Journal of Botany, 87:783–792.

Godt, M.J.W., B.R. Johnson, and J.L. Hamrick. 1996. Genetic diversity and population size in four rare southern Applachian plant species. Conservation Biology, 10:796–805.

———, F. Caplow, and J.L. Hamrick. 2005. Allozyme diversity in the federally threatened golden paintbrush, *Castilleja levisecta* (Scrophulariaceae). Conservation Genetics, 6:87–99.

Gram, W.K. and V.L. Sork. 1999. Population density as a predictor of genetic variation for woody plant species. Conservation Biology, 13:1079–1087.

Halliburton, R. 2004. Introduction to Population Genetics. Pearson Prentice Hall, Upper Saddle River, New Jersey, USA. xxi+650 pp.

Hamrick, J.L. and M.J.W. Godt. 1989. Allozyme diversity in plant species. In (H.D. Brown, M.T. Clegg, A.L. Kahler, and B.S. Weir, eds.). Plant Population Genetics, Breeding, and Genetic Resources, Pp. 43–63, Sinauer Associates, Inc., Sunderland, Massachusetts, USA. xii+449 pp.

———, Y.B. Linhart, and J.B. Mitton. 1979. Relationships between life history characteristics and electrophoretically–detectable genetic variation in plants. Annual Review of Ecology and Systematics, 10:173–200.

———, M.J.W. Godt, D.A. Murawski, and M.D. Loveless. 1991. Correlations between species traits and allozyme diversity: Implications for conservation biology. In (D.A. Falk and K.E. Holsinger, eds.). Genetics and Conservation of Rare Plants, Pp. 75–86, Oxford University Press, New York, New York, USA. xviii+283 pp.

Handel, S.N. 1983. Pollination ecology, plant population structure, and gene flow. In (L.A. Real, ed.). Pollination Biology, Pp. 163–211, Academic Press, Orlando, Florida, USA. 356 pp.

Juan, A., M.B. Crespo, R.S. Cowan, C. Lexer, and M.F. Fay. 2004. Patterns of variability and gene flow in *Medicago citrine*, an endangered endemic of islands in the western Mediterranean, as revealed by amplified fragment length polymorphism (AFLP). Molecular Ecology, 13:2679–2690.

Judd, W.S., C.S. Campbell, E.A. Kellogg, P.F. Stevens, and M.J. Donoghue. 2002. Plant Systematics: A Phylogenetic Approach, 2nd ed. Sinauer Associates, Inc., Sunderland, Massachusetts, USA. xvi+576 pp.

Karron, J.D. 1987a. The pollination ecology of co-occurring geographically restricted and widespread species of *Astragalus* (Fabaceae). Biological Conservation, 39:179–193.

———. 1987b. A comparison of levels of genetic polymorphism and self-compatibility in geographically restricted and widespread plant congeners. Evolutionary Ecology, 1:47–58.

———. 1989. Breeding systems and levels of inbreeding depression in geographically restricted and widespread species of *Astragalus* (Fabaceae). American Journal of Botany, 76:331–340.

———. 1991. Patterns of genetic variation and breeding systems in rare plant species in genetics and conservation of rare plants. In D.A. Falk, and K.E. Holsinger (EDITORS) 1991. Genetics and Conservation of Rare Plants, Pp. 87–98, Oxford University Press, New York, New York, USA. xviii+283 pp.

———, Y.B. Linhart, C.A. Chaulk, and C.A. Robertson. 1988. Genetic structure of populations of geographically restricted and widespread species of *Astragalus* (Fabaceae). American Journal of Botany, 75:1114–1119.

———, N.N. Thumser, R. Tucker, and A.J. Hessenauer. 1995. The influence of population density on outcrossing rates in *Mimulus ringens*. Heredity, 75:175–180.

Kingston, S.E. and P.E. Rosel. 2004. Genetic differentiation among recently diverged delphinid taxa determined using AFLP markers. Journal of Heredity, 95:1–10.

Lanteri, S., E. Saba, M. Cadinu, G.M. Mallica, L. Baghino, and E. Portis. 2004. Amplified fragment length polymorphism for genetic diversity assessment in globe artichoke. Theoretical and Applied Genetics, 108:1534–1544.

Legendre, P. and L. Legendre. 1998. Numerical Ecology, 2nd ed. Elsevier Scientific Publishing Company, Amersterdam, The Netherlands. xv+853 pp.

Levin, D.A. and H. Kerster. 1969a. Density-dependent gene dispersal in Liatris. The American Naturalist, 103:61–74.

——— and H.W. Kerster. 1969b. The dependence of bee-mediated pollen and gene dispersal upon plant density. Evolution, 23:560–571.

Lihova, J., J.F. Aguilar, K. Marhold, and G.N. Feliner. 2004. Origin of the disjunct tetraploid *Cardamine amporitana* (Brassicaceae) assessed with nuclear and chloroplast DNA sequence data. American Journal of Botany, 91:1231–1242.

Loveless, M.D. and J.L. Hamrick. 1984. Ecological determinants of genetic structure in plant populations. Annual Review of Ecology and Systematics, 15:65–95.

Lu, Y., D.M. Waller, and P. David. 2005. Genetic variability is correlated with population size and reproduction in American wild-rice (*Zizania palustris* var. *palustris*, Poaceae) populations. American Journal of Botany, 92:990–997.

Lynch, M. 1996. A quantitative-genetic perspective on conservation issues. In (J.C. Avise and J.L. Hamrick, eds.). Conservation Genetics: Case Histories from Nature, Pp. 471–501, Chapman and Hall, New York, New York, USA.

Mace, G.M. and R. Lande. 1991. Assessing extinction threats: toward a reevaluation of IUCN threatened species categories. Conservation Biology, 5:148–157.

Mantel, N.A. 1967. The detection of disease clustering and generalized regression approach. Cancer Research, 27:209–220.

Miller, M.P. 2000. Tools for population genetic analysis (TFPGA): a Windows program for the analyses of alloyzme and molecular population genetic data, version 1.3. Website http://bioweb.usu.edu/mpmbio/tfpga.asp [Accessed 15 January 2005].

Mueller, U.G. and L.L. Wolfenbarger. 1999. AFLP genotyping and fingerprinting. Trends in Ecology and Evolution, 14:389–394.

Muellner, A.N., K. Tremetsberger, T. Stuessy, and C.M. Baeza. 2005. Pleistocene refugia and recolonization routes in the southern Andes: insights from *Hypochaeris palustric* (Asteraceae, Lactuceae). Molecular Ecology, 14:203–212.

Mullis, K., F. Faloona, S. Scharf, R. Saiki, G. Horn, and H. Erlich. 1986. Specific enzymatic amplification of DNA in vitro: the polymerase chain reaction. Cold Spring Harbor Symposium in Quantitative Biology, 51:263–273.

Munz, P.A. 1941. Interesting western plants-V. Leaflets of western Botany, 3:49–50.

Nei, M. 1978. Estimation of average heterozygosity and genetic distance from a small number of individuals. Genetics, 89:583–590.

———. 1987. Molecular Evolutionary Genetics. Columbia University Press, New York, New York, USA. x+512 pp.

Neigel, J.E. 1997. A comparison of alternative strategies for estimating gene flow from genetic markers. Annual Review of Ecology and Systematics, 28:105–128.

Nunney, L. 2000. The limits to knowledge in conservation genetics: the predictive value of effective population size. In (M.T. Clegg, M.K. Hecht, and R.J. MacIntyre, eds.). Evolutionary Biology, Volume 32: Limits to Knowledge in Evolutionary Genetics, Pp. 179–194, Plenum Press, New York, New York, USA. xvi+258 pp.

Nybom, H. 2004. Comparison of different nuclear DNA markers for estimating intraspecific genetic diversity in plants. Molecular Ecology, 13:1143–1155.

Prigge, B.A., M.R. Sharifi, and D. Morafka. 2000. Lane Mountain milk-vetch surveys (Progress Report III). Prepared for the National Training Center, U.S. Department of the Army, Contract No. DSCA05-99-P-0759. Dominguez Hills Foundation, Carson, California, USA.

Proctor, M., P. Yeo, and A. Lack. 1996. The Natural History of Pollination. Timber Press, Portland, Oregon, USA. 479 pp.

Richards, C.M., S. Church, and D.E. McCauley. 1999. The influence of population size and isolation on gene flow by pollen in *Silene alba*. Evolution, 53:63–73.

Ritland, C. and K. Ritland. 2000. DNA-fragment markers in plants. In (A.J. Baker, ed.). Molecular Methods in Ecology, Pp. 208–234, Blackwell Science, Ltd., Oxford, UK. x+337 pp.

Roll, J., R.J. Mitchell, R.J. Cabin, and D.L. Marshall. 1997. Reproductive success increases with local density of conspecifics in the desert mustard *Lesquerella fendleri*. Conservation Biology, 11: 738–746.

Ruggiero, M.V. and G. Procaccini. 2004. The rDNA ITS region in the Lessepsian marine angiosperm *Halophila stipulacea* (Forssk.) Aschers. (Hydrocharitaceae): intragenomic variability and putative pseudogenic sequences. Journal of Molecular Evolution, 58:115–121.

Schmidt, K. and K. Jensen. 2000. Genetic structure and AFLP variation of remnant populations in the rare plant *Pedicularis palustris* (Scrophulariaceae) and its relation to population size and reproductive components. American Journal of Botany, 87:678–689.

Schneider, S., D. Roessli, and L. Excoffier. 2000. ARLEQUIN, version 2.0: a Software for Population Genetics Data Analysis. Genetics and Biometry Laboratory. University of Geneva, Switzerland, Website http://lgb.unige.ch/arlequin/ [Accessed 5 January 2005].

Shaw, J., E.B. Lickey, J.T. Beck, S.B. Farmer, W. Liu, J. Miller, K.C. Siripun, C.T. Winder, E.E. Schilling, and R.L. Small. 2005. The tortoise and the hare II: relative utility of 21 noncoding chloroplast DNA sequences for phylogenetic analysis. American Journal of Botany, 92:142–166.

Slatkin, M. 1985. Gene flow in natural populations. Annual Review of Ecology and Systematics, 16: 393–340.

Soltis, P.S. and D.E. Soltis. 1991. Genetic variation in endemic and widespread plant species: examples from Saxifragaceae and *Polystichum* (Dryopteridaceae). Aliso, 13:215–223.

Swofford, D.L. 1998. *PAUP*, version 4.0d64 for Macintosh. Sinauer Associates, Northampton, Massachusetts, USA.

Taberlet, P., L. Gielly, G. Pautou, and J. Bouvet. 1991. Universal primers for amplification of three non-coding regions of chloroplast DNA. Plant Molecular Biology, 17:1105–1109.

Tang, T., Y. Zhong, S. Jian, and S. Shi. 2003. Genetic diversity of *Hibiscus tiliaceus* (Malvaceae) in China assessed using AFLP markers. Annals of Botany (London), 92:409–414.

Terry, R.G., R.S. Nowak, and R.J. Tausch. 2000. Genetic variation in chloroplast and nuclear ribosomal DNA in Utah juniper (*Juniperus ostersperma*, Cupressaceae): evidence for interspecific gene flow. American Journal of Botany, 87:250–258.

Travis, S.E., J. Maschinski, and P. Keim. 1996. An analysis of genetic variation in *Astragalus cremnophylax* var. *cremnophylax*, a critically endangered plant, using AFLP markers. Molecular Ecology, 5:735–745.

Tucker, S.C. 2003. Floral development in Legumes. Plant Physiology, 131:911–926.

U.S. Fish and Wildlife Service. 2001. Draft recovery plan for the Lane Mountain milkvetch (*Astragalus jaegerianus*). USDI Fish and Wildlife Service, Portland, Oregon, USA.

Van Treuren, R., R. Bulsma, N.J. Ouborg, and W. Van Delden. 1993. The effects of population size and plant density on outcrossing rates in locally endangered *Salvia pratensis*. Evolution, 47:1094–1104.

Vekemans, X., T. Beauwens, M. Lemaire, and I. Roldan-Ruiz. 2002. Data from amplified fragment length polymorphism (AFLP) markers show indication of size homoplasy and of a relationship between degree of homoplasy and fragment size. Molecular Ecology, 11:139–151.

Vilatersana, R., A. Susanna, and C. Brochmann. 2007. Genetic variation in *Femeniasia* (Compositae, Cardueae), an endemic and endangered monotypic genus from the Balearic Islands (Spain). Botanical Journal of the Linnean Society, 153:97–107.

Vos, P., R. Hogers, M. Bleeker, M. Reijans, T. van de Lee, M. Hornes, A. Frijters, J. Pot, J. Peleman, M. Kuiper, and M. Zabeau. 1995. AFLP®: a new technique for DNA fingerprinting. Nucleic Acids Research, 23:4405–4414.

Weir, B.S. 1996. Genetic Data Analysis II. Sinauer Associates, Sunderland, Massachusetts, USA. xii+445 pp.

——— and C.C. Cockerham. 1984. Estimating *F*-statistics for the analysis of population structure. Evolution, 38:1358–1370.

White, T.J., T. Bruins, S. Lee, and J. Taylor. 1989. Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In (M.A. Innis, D.H. Gelfand, and J.J. White, eds.). PCR Protocols: A Guide to Methods and Applications, Pp. 315–322, Academic Press Inc., San Diego, California, USA. x+482 pp.

Whitlock, M.C. and D.E. McCauley. 1999. Indirect measures of gene flow and migration: $F_{ST} \neq 1/(4\ Nm + 1)$. Heredity, 82:117–125.

Winfield, M.O., G.M. Arnold, R. Cooper, M. LeRay, J. White, A. Karp, and K.J. Edwards. 1998. A study of genetic diversity in *Populus nigra* subsp. *betulifolia* in the upper Severn area of the UK using AFLP markers. Molecular Ecology, 7:3–10.

Wright, S. 1931. Evolution in Mendelian populations. Genetics, 16:97–159.

———. 1951. The general structure of populations. Annals of Eugenetics, 1:323–334.

Yeh, F.C., R.-C. Yang, and T. Boyle. 1999. POPGENE, version 1.31. Microsoft Window-based freeware for population genetic analysis, University of Alberta, Edmonton, Website http://www.ualberta,ca/~fyeh/index.htm/ [Accessed 15 December 2004].

Accepted for publication 11 December 2007.

Bull. Southern California Acad. Sci.
107(3), 2008, pp. 178–182

Research Notes

Impacts of Cotyledon Removal on Survival of Blackbrush (*Coleogyne ramosissima*: Rosaceae) Seedlings

Simon A. Lei

Department of Educational Psychology, University of Nevada, Las Vegas
4505 Maryland Parkway, Las Vegas, NV 89154-3003

Introduction

Despite the ecological importance of the regeneration stage of plant life histories (Grime 2001), some of the factors affecting seedling survival, including the interaction between seedlings and their herbivores, are not well-understood (Hanley and May 2006). Herbivory is a major cause of seedling mortality for many woody plant species (Hanley 1998; Moles and Westoby 2004; Fenner and Thompson 2005). The ability of seedlings to cope with herbivory is likely affected by seed size, the presence or absence of cotyledons, and the time elapsed since germination (Bonfil 1998).

Because seedlings of woody plant species are small, they can suffer high mortality due to herbivory (Kitajima and Augspurger 1989; Howe 1990; Osunkoya et al. 1992; Asquith et al. 1997; Kitajima 2003). Carbohydrate reserves are important for seedling recovery after tissue loss, especially in shaded understories where photosynthesis is limited (McPherson and Williams 1998; Canham et al. 1999). Cotyledons can support energy and nutrient demands of a young seedling either as photosynthetic or reserve organs (Kitajima 2003). Cotyledons have nutritional value, and it is common to find young seedlings in the field with cotyledons that have been partially or completely removed by insects and browsing vertebrates (Smythe 1978). Such removal of cotyledons before development of the first true leaf is usually fatal (Kitajima 2003). However, even after development of the first leaf, cotyledon loss may greatly reduce seedling survival (Kitajima 2003).

Using greenhouse experiments, I investigated how the timing of cotyledon damage and variation in its magnitude influencing survival of young blackbrush (*Coleogyne ramosissima* Torr.) seedlings through simulated cotyledon herbivory. Specifically, I examined whether differences in the ability of 4-month-old *Coleogyne* seedlings to survive detachment of cotyledons were related to the timing and extent of cotyledon removal in an environmentally controlled greenhouse.

Methods

Seed Collection and Germination

Coleogyne seeds were collected from late June through early August 2006 in Cold Creek Canyon that lies on the eastern slope of the Spring Mountains (36° 25′N, 115° 28′W; 1,250 to 1,405 m in elevation). The Spring Mountains are located approximately 65 km northwest of the Las Vegas Valley in southern Nevada. A total of 500 potentially viable seeds were collected from nearly monospecific *Coleogyne* shrublands.

Tel: (702) 895-3953, Fax: (702) 895-1658, E-mail: leis2@unlv.nevada.edu

Coleogyne seeds were placed at room temperature (22° C) for 4–5 months prior to the initiation of the pot trial experiments. These seeds were stored at 4° C for six weeks in the dark (dry-chilling) to obtain maximum germination (Lei 1997). A relatively long, dry-chilling was required for complete removal of dormancy for seeds especially found at high elevations (Meyer and Pendleton 1990).

During the germination period, 20 seeds were placed between two layers of germination blotters moistened with tap water inside a 10-cm diameter Petri dish. Stacks of Petri dishes were placed in transparent zip-loc bags in a cool chamber to decrease evaporative water loss, and water was added as necessary to maintain saturation of blotters during incubation. *Coleogyne* seeds were incubated at 4° C in the dark except for an occasional, brief exposure to fluorescent light. Germination of most seeds was observed 2–3 weeks into the initial experiment. Seed germination was monitored and recorded for 34 days. Radicle emergence greater than 1 mm was the criterion for seed germination, and over 85% of seeds germinated.

Pot Trial Experiments

Five-week old *Coleogyne* seedlings were planted into 65-mm diameter * 350-mm tall, cone-shaped containers. Pots were randomly arranged in a greenhouse from mid-December 2006 through mid-April 2007. Each pot contained one-third of perlite and two-thirds of natural field soil, thoroughly mixed, without adding fertilizers in order to maintain a low soil fertility level. Perlite was used to enhance aeration and drainage (Lei 2004 and 2006).

Prior to planting, care was taken to allocate seedlings by size to various experimental treatments, so that no single treatment had disproportionally large or small seedlings. Pots were lightly moistened with tap water for 17 weeks (four months) in the greenhouse. Initially, seedlings were watered twice a week for the first three weeks, and thereafter once a week until the end of the pot trial experiments. A small amount of liquid fungicide (Banner Maxx Systematic Fungicide) was applied biweekly. Any deaths observed during the first several days were immediately replaced with new *Coleogyne* seedlings. Survivorship percentages among seven treatment groups were recorded, with 30 individuals in each group for a total of 210 seedlings. During the course of study, light and air temperature regime in the greenhouse resembled winter and spring weather conditions in *Coleogyne* shrublands at mid-elevations of southern Nevada.

Herbivory treatments were applied to *Coleogyne* seedlings. These treatments included timing (control, early, and late) of cotyledon removal. The early removal treatment had both cotyledons excised before appearance of the first set of true leaves, while the later removal treatment had both cotyledons excised shortly after development of the first set of leaves.

In addition, cotyledons were excised with scissors as a gradient of 0% (control), 50% (half), and 100% (all). This herbivory treatment was applied 4 and 21 days after planting into a plastic pot to simulate the extent of cotyledon removal by herbivores before and after the emergence of the first set of true leaves. The 50% removal treatment had one cotyledon excised, while the 100% removal treatment had both cotyledons excised. Scissors were sterilized in 70% isopropyl alcohol between clippings in order to minimize pathogen spread among *Coleogyne* seedlings.

Survivorship of *Coleogyne* seedlings was assessed based on the presence of green leaves and growing shoots. Four months after simulated cotyledon herbivory, seedlings were classified into two categories: alive or dead. Surviving seedlings exhibited net growth, whereas dead seedlings exhibited no growth, with brittle, dark brown leaves.

Table 1. Survivorship of *Coleogyne* seedlings and results of Chi-square (X^2) analysis showing the timing of cotyledon damage and variation in its magnitude using greenhouse experiments ($n = 30$ per treatment group in each variable). Survivorship was based on four months after simulated cotyledon herbivory. Statistical significance is determined at $p \leq 0.05$.

Variable	Survival proportion (%)	X^2	p-value
Control	76.7		
Timing of cotyledon removal		4.32	0.0377
Early (before first set of leaves)	0		
Late (after first set of leaves	40.0		
Extent of removal (before first set of leaves)		6.41	0.0114
Partial (50%)	16.7		
Total (100%)	0		
Extent of removal (after first set of leaves)		4.02	0.0449
Partial (50%)	26.7		
Total (100%)	16.7		

Statistical Analyses

Proportion of *Coleogyne* seedlings that survived four months after simulated cotyledon herbivory was computed. The experimental treatments included timing of cotyledon removal, as well as extent of cotyledon removal before and after the development of the first set of true leaves. Chi-square analysis, with Yate's correction (Analytical Software 2007), was performed to determine significant difference in mortality, with timing and extent of cotyledon removal as main effects. Statistical significance was determined at $p \leq 0.05$.

Results

Coleogyne cotyledons appeared 12 to 17 days after initial seed germination. Serving as photosynthetic leaves, many cotyledons turned green within 9 days after planting into a pot containing soil mix. Cotyledon length and width (dimensions) were substantially greater than true leaf dimensions. In general, the first set of leaves appeared 13 to 19 days after planting into a pot, and was fully developed 5 to 9 more days after initial appearance. At the same time, additional true leaves began to emerge.

Cotyledon excision had more adverse effects on *Coleogyne* seedling survival than the control group. Because some individuals were alive at the end of this study, survival difference among seven experimental treatments was observed and summarized as proportion surviving after four months (Table 1).

Survivorship of *Coleogyne* seedlings was significantly higher when cotyledons remained intact (control) compared to cotyledons severed before development of the first set of true leaves ($p \leq 0.05$; Table 1). Similarly, survivorship of seedlings was significantly higher when cotyledons remained intact compared to partial or total excision of cotyledons regardless of the presence of the first set of true leaves ($p \leq 0.05$; Table 1).

Discussion

Results of this study support and reinforce the role of cotyledons on early seedling survival of *Coleogyne*. Herbivory can be potentially large during the early seedling life (Hanley and May 2006). Simulated herbivory at the cotyledon stage significantly decreased the probability of *Coleogyne* seedling survival. The timing and extent of cotyledon loss significantly influenced subsequent seedling survival.

Cotyledons apparently contributed to the energy demand of *Coleogyne* seedlings at a very early stage. Resources transferred from cotyledons to the rest of the seedling during this period are important for survival, even after seedlings had fully expanded leaves apparently available for photosynthetic carbon gain (Kitajima 2003). Without cotyledons, the presence of even a small leaf was critical for survival in this study. All seedlings died after both cotyledons were excised before the emergence of the first set of true leaves.

Survival of *Coleogyne* seedlings was significantly reduced by partial or total cotyledon removal, demonstrating that seeds reserves were stored in cotyledons before and several weeks after germination. Partial or total removal of cotyledons can cause death in young seedlings of woody plant species (Mulligan and Patrick 1985; Armstrong and Westoby 1993). Cotyledons would be important for energy acquisition in seedlings (Milberg and Lamont 1997). Vertebrate and invertebrate herbivores (predators) would prefer to excise the cotyledons as early as possible before their food reserves are completely consumed by the seedlings (Bonfil 1998). Seedlings are unable to survive if cotyledons are defoliated 7 to 15 days after germination (Bonfil 1998), which is in agreement with this study.

In the field, *Coleogyne* seedling survival is influenced by a number of factors in southern Utah and Nevada (Meyer and Pendleton 2005). Most mortality took place early in the first year. Early spring mortality was primarily due to animal (rodent) grazing the new sprouts (Meyer and Pendleton 2005). The seedling-eating rodent communities are comprised of a mixture of heteromyid and non-heteromyid species. If seedlings survive this "rodent sieve", drought-related mortality may occur in late May through early June (Meyer and Pendleton 2005). A majority of seedlings that survived the first summer also survived through the second summer (Meyer and Pendleton 2005).

By reducing shrub seedling survival, herbivory can have adverse effects on the establishment of shrubs in successional systems (Meiners and Handel 2000). Microsites and periods where seedlings are exposed to herbivory could be characterized by high seedling mortality, making successful establishment unlikely (Meiners and Handel 2000). When herbivory is low, establishment rates should be high, resulting in the establishment of a cohort of seedlings (Meiners and Handel 2000). A brief period of low herbivory can result in a window of establishment in successional time (Rankin and Pickett 1989; Peroni 1994).

Acknowledgments

I gratefully acknowledge Steven Lei, David Valenzuela, and Shevaun Valenzuela for collecting *Coleogyne* seeds in the field and for setting up various experimental treatments in a greenhouse at College of Southern Nevada (CSN). Helpful comments provided by Steven Lei greatly improved this manuscript.

Literature Cited

Analytical Software. 2007. Statistix 8.0, an interactive statistical program for microcomputers. Analytical Software, St. Paul, Minnesota.

Armstrong, D.P. and M. Westoby. 1993. Seedlings from large seeds tolerate defoliation better: a test using phylogenetically independent contrasts. Ecology, 74:1092–1116.

Asquith, N.W., S.J. Wright, and M.J. Clauss. 1997. Does mammal community composition control recruitment in neotropical forest? Evidence from Panama. Ecology, 78:941–946.

Bonfil, C. 1998. The effects of seed, size cotyledon reserves, and herbivory on seedling survival and growth in *Quercus rugosa* and *Q. laurina* (Fagaceae). American Journal of Botany, 85:79–87.

Canham, C.D., R.K. Kobe, E.F. Latty, and R.L. Chazdon. 1999. Interspecific and intraspecific variation in tree seedling survival: effects of allocation to roots versus carbohydrate reserves. Oecologia, 121: 1–11.

Fenner, M. and K. Thompson. 2005. The ecology of seeds, second edition. Cambridge University Press, Cambridge, United Kingdom.

Grime, J.P. 2001. Plant strategies, vegetation processes and ecosystem properties, second edition. Wiley and Sons, Chichester, United Kingdom.

Hanley, M.E. 1998. Seedling herbivory, community composition and plant life history traits. Perspectives in Plant Ecology, Evolution and Systematics, 1:191–205.

——— and O.C. May. 2006. Cotyledon damage at the seedling stage affects growth and flowering potential in mature plants. New Phytologist, 169:243–250.

Howe, H.F. 1990. Survival and growth of juvenile *Virola surinamesis* in Panama: effects of herbivory and canopy closure. Journal of Tropical Ecology, 6:259–280.

Kitajima, K. and C.K. Augspurger. 1989. Seed and seedling ecology of a monocarpic tropical tree, *Tachigalia versicolor*. Ecology, 70:1102–1114.

———. 2003. Impact of cotyledon and leaf removal on seedling survival in three species with contrasting cotyledon functions. Biotropica, 35:429–434.

Lei, S.A. 1997. Variation in germination response to temperature and water availability in blackbrush (*Coleogyne ramosissima*) and its ecological significance. Great Basin Naturalist, 57:172–177.

———. 2004. Intraspecific competition among blackbrush (*Coleogyne ramosissima*) seedlings in a controlled environmental glasshouse. Arizona-Nevada Academy of Science, 37:100–104.

———. 2006. Interspecific competition between *Coleogyne ramosissima* seedlings and *Bromus rubens*. Southern California Academy of Sciences, 105:76–84.

McPherson, K. and K. Williams. 1998. The role of carbohydrate reserves in the growth, resilience, and persistence of cabbage palm seedlings (*Sabal palmetto*). Oecologia, 117:460–468.

Meiners, S.J. and S.N. Handel. 2000. Additive and nonadditive effects of herbivory and competition on tree seedling mortality, growth and allocation. American Journal of Botany, 87:1821–1826.

Meyer, S.E. and R.L. Pendleton. 1990. Seed germination biology of spineless hopsage: between population differences in dormancy and response to temperature. Paper presented at the symposium on cheatgreass invasion, shrub die-off, and other aspects of shrub biology and management. Las Vegas, NV, 5–7 April 1989.

——— and B.K. Pendleton. 2005. Factors affecting seed germination and seedling establishment of a long-lived desert shrub (*Coleogyne ramosissima*: Rosaceae). Plant Ecology, 178:171–187.

Milbert, P. and B.B. Lamont. 1997. Seed/cotyledon size and nutrient content play a major role in early performance of species on nutrient-poor soils. New Phytologist, 137:665–672.

Moles, A.T. and M. Westoby. 2004. What do seedlings die from and what are the implications for evolution of seed size? Oikos, 106:193–199.

Mulligan, D.R. and J.W. Patrick. 1985. Carbon and phosphorus assimilation and deployment in *Eucalyptus piluraris* seedlings with special reference to the role of cotyedons. Australian Journal of Botany, 33:485–496.

Osunkoya, O.O., J.E. Ash, M.S. Hopkins, and A.W. Graham. 1992. Factors affecting survival of tree seedlings in North Queensland rainforests. Oecologia, 91:569–578.

Peroni, P.A. 1994. Invasion of red maple (*Acer rubrum*) during old-field succession in the North Carolina Piedmont: age structure of red maple in young pine stands. Bulletin of the Torrey Botanical Club, 121:357–359.

Rankin, W.T. and S.T.A. Pickett. 1989. Timing of establishment of red maple (*Acer rubrum*) in early old-field succession. Bulletin of the Torrey Botanical Club, 116:182–186.

Smythe, N. 1987. The natural history of the Central American agouti (*Dasyprocta punctata*). Smithsonian Contribution to Zoology, 157:1–52.

Bull. Southern California Acad. Sci.
107(3), 2008, pp. 183–186

Length-Weight Relationships of Select Common Nearshore Southern California Marine Fishes

Eric F. Miller,[1] D. Shane Beck, and Wayne Dossett

MBC Applied Environmental Sciences, 3000 Red Hill Ave., Costa Mesa, CA 92626

Growth dynamics of marine fish is often critical for fisheries analysis. Frequently only lengths are measured during ecological surveys, occasionally with aggregate weights by species (Allen and Herbinson 1990; Pondella and Allen 2000; Allen et al. 2002). This information often allows for estimation of age-class composition through length frequency analysis, but can mask the importance of individual fish weights to the overall community structure, such as the inclusion of one, or a few, large individuals among a predominantly small catch. Over time, authors have reported length-to-weight relationships for specific species in the course of specific life history investigations, but these studies are rarely conducted on forage species. Cailliet et al. (2000) compiled many of the relationships that were available at the time, but numerous species still lack such basal information. Their database, however, contained 124 species, many of which did not have length-weight relationships available. Love et al. (2002) also compiled additional information on several rockfish species (*Sebastes* spp) and *Sebastolobus alascanus.*

Since 1979, impingement surveys at coastal generating stations routinely recorded the length of nearly all impinged fish during a given survey. Most of these surveys, however, recorded the aggregate weight by species, a protocol consistent with most ecological studies in southern California. Specific, focused studies were occasionally undertaken during which the individual length and weight of a subset of individuals were recorded. Moreover, instances when only a single individual of a specific species was impinged, a defacto length-weight relationship data point was recorded. During these studies the appropriate length; standard (SL), total (TL), or disc width (DW) was measured to the nearest millimeter (mm) and weight recorded to the nearest gram (g).

Data from impingement records 2001–2006, recorded at generating stations from San Diego County to Los Angeles County, California were reviewed to generate species-specific length-weight relationships (Tables 1 and 2). A total of 59 species were identified with length and weight recorded for greater than 10 individuals. These included both 54 ray-finned fishes (Class Actinopterygii) and 5 elasmobranch species (Subclass Elasmobranchii). All were common to the Southern California Bight (Miller and Lea 1972; Love et al. 2005). Forty-two of these species were included in the Cailliet et al. (2000) species list, but only 27 had a length-weight relationship listed.

The length-weight relationships of fishes typically fit the non-linear equation $W = aL^b$, where W = weight (g), L = length (mm), and a and b are derived constants. A best fit line was plotted for each distribution using MS Excel. The determination of the best fit was based on the R^2-value. Fifty-six species were best described by the traditional non-linear equation $W = aL^b$. Two species, *Anchoa compressa* and *A. delicatissima* were best described by a linear relationship and one species, *Seriphus politus*, was best described by an exponential function. The minimum and maximum length (mm) recorded for each

---

[1] Corresponding Author: emiller@mbcnet.net

Table 1. Length (mm)-weight (g) relationship, tightness of fit to the equation (R^2), sample size, and minimum and maximum length recorded for 54 fish species (Class Actinopterygii) collected during impingement sampling from Los Angeles County to San Diego County, California from 2001–2006, mainly 2006.

Species	Equation	R^2	N	Min. Len. (mm)	Max. Len. (mm)
Acanthogobius flavimanus	Wt = 2E-05SL$^{2.8272}$	0.84	67	70	183
Anchoa compressa	Wt = 0.3SL-0.0164	0.78	187	62	126
Anchoa delicatissima	Wt = 0.2SL - 0.0123	0.76	119	40	129
Anisotremus davidsonii	Wt = 2E-05SL$^{3.0457}$	0.99	45	41	327
Atherinops affinis	Wt = 2E-06SL$^{3.3046}$	0.96	1499	22	286
Atherinopsis californiensis	Wt = 2E-055SL$^{2.9051}$	0.89	668	48	342
Atractoscion nobilis	Wt = 4E-05SL$^{2.7991}$	0.98	65	64	420
Brachyistius frenatus	Wt = 5E-06SL$^{3.3596}$	0.93	22	70	128
Chilara taylori	Wt = 1E-06SL$^{3.2744}$	0.92	18	140	226
Chromis punctipinnis	Wt = 2E-05SL$^{3.1244}$	0.97	133	28	238
Citharichthys stigmaeus	Wt = 2E-05SL$^{3.0021}$	0.87	165	22	116
Cymatogaster aggregata	Wt = 2E-05SL$^{3.0583}$	0.95	824	29	161
Embiotoca jacksoni	Wt = 8E-06SL$^{3.3244}$	0.98	413	47	256
Fundulus parvipinnis	Wt = 8E-05SL$^{2.6197}$	0.87	14	48	70
Genyonemus lineatus	Wt = 1E-05SL$^{3.1249}$	0.98	389	28	252
Gibbonsia elegans	Wt = 6E-06SL$^{3.171}$	0.92	32	48	160
Gillichthys mirabilis	Wt = 1E-04SL$^{2.4415}$	0.87	112	25	154
Girella nigricans	Wt = 2E-05SL$^{3.124}$	0.98	21	75	332
Halichoeres semicinctus	Wt = 5E-06SL$^{3.2776}$	0.95	33	136	286
Heterostichus rostratus	Wt = 7E-06SL$^{3.0407}$	0.95	131	33	325
Hyperprosopon argenteum	Wt = 1E-05SL$^{3.2295}$	0.97	274	42	168
Hypsoblennius gilberti	Wt = 6E-05SL$^{2.7702}$	0.88	87	31	113
Hypsurus caryi	Wt = 2E-05SL$^{3.051}$	0.99	27	50	186
Leptocottus armatus	Wt = 2E-05SL$^{2.9422}$	0.94	326	32	185
Leuresthes tenuis	Wt = 7E-06SL$^{3.043}$	0.95	125	31	165
Medialuna californiensis	Wt = 3E-05SL$^{3.0106}$	0.97	12	145	224
Menticirrhus undulatus	Wt = 2E-05SL$^{2.9383}$	0.99	72	56	375
Ophichthus zophochir	Wt = 1E-12SL$^{5.1724}$	0.91	11	419	672
Ophidion scrippsae	Wt = 4E-08SL$^{3.9624}$	0.96	14	130	249
Oxyjulis californica	Wt = 2E-05SL$^{2.939}$	0.92	35	82	180
Paralabrax clathratus	Wt = 4E-05SL$^{2.9184}$	0.98	242	25	402
Paralabrax nebulifer	Wt = 3E-05SL$^{2.9802}$	0.99	150	27	435
Paralichthys californicus	Wt = 8E-05SL$^{2.6813}$	0.88	53	41	508
Peprilus simillimus	Wt = 1E-05SL$^{3.1729}$	0.90	160	45	175
Phanerodon furcatus	Wt = 2E-05SL$^{3.053}$	0.97	150	33	200
Pleuronichthys guttulatus	Wt = 4E-05SL$^{2.9106}$	0.99	61	27	375
Pleuronichthys ritteri	Wt = 2E-05SL$^{3.083}$	0.97	185	20	245
Pleuronichthys verticalis	Wt = 3E-05SL$^{2.9387}$	0.98	40	54	294
Porichthys myriaster	Wt = 1E-05SL$^{2.9407}$	0.97	230	19	476
Porichthys notatus	Wt = 8E-06SL$^{3.0692}$	0.98	25	37	266
Rhacochilus toxotes	Wt = 2E-05SL$^{3.0787}$	0.99	98	68	281
Rhacochilus vacca	Wt = 4E-05SL$^{2.9363}$	0.97	69	54	276
Scomber japonicus	Wt = 8E-06SL$^{3.0902}$	0.85	272	74	363
Scorpaena guttata	Wt = 4E-05SL$^{2.981}$	0.98	145	29	293
Scorpaenichthys marmoratus	Wt = 3E-05SL$^{2.9904}$	0.97	37	79	285
Sebastes auriculatus	Wt = 2E-05SL$^{3.0945}$	0.95	51	110	316
Sebastes miniatus	Wt = 5E-05SL$^{2.9095}$	0.99	12	39	290

Table 1. Continued.

Species	Equation	R^2	N	Min. Len. (mm)	Max. Len. (mm)
Seriphus politus	$Wt = 0.3e^{0.0373SL}$	0.93	3073	11	193
Sphyraena argentea	$Wt = 5E\text{-}06SL^{3.0316}$	0.97	31	45	406
Symphurus atricaudus	$Wt = 8E\text{-}04SL^{2.0957}$	0.91	18	22	179
Synodus lucioceps	$Wt = 4E\text{-}06SL^{3.1072}$	0.87	85	26	221
Trachurus symmetricus	$Wt = 7E\text{-}06SL^{3.1246}$	0.91	159	60	241
Umbrina roncador	$Wt = 3E\text{-}058SL^{2.9233}$	0.99	73	72	301
Xenistius californiensis	$Wt = 2E\text{-}05SL^{3.0349}$	0.94	265	29	173

Table 2. Length (mm)-weight (g) relationships of fit to the equation (R^2), sample size, and minimum and maximum length recorded for five elasmobranch (Subclass Elasmobranchii) species collected during impingement sampling from Los Angeles County to San Diego County, California from 2001–2006, mainly 2006.

Species	Equation	R^2	N	Min. Len. (mm)	Max. Len. (mm)
Heterodontus francisci	$Wt = 9E\text{-}06TL^{2.9948}$	0.98	19	112	750
Myliobatis californica	$Wt = 1E\text{-}05DW^{3.0436}$	0.95	446	167	885
Platyrhinoidis triseriata	$Wt = 7E\text{-}06TL^{2.9774}$	0.98	102	115	670
Torpedo californica	$Wt = 7E\text{-}05TL^{2.7748}$	0.90	50	185	932
Urobatis halleri	$Wt = 3E\text{-}05DW^{3.1312}$	0.88	960	68	366

species was included, as some of these relationships may not fully encapsulate the total available size range commonly occurring in the Southern California Bight. These relationships were not compared to previous published results, but rather presented purely based on the available data recorded during impingement surveys so as to represent a recent assessment of length-weight relationships of common marine fish.

Acknowledgements

We would like to thank R. Moore and M. Love, whose questions and support spurred the compilation of this data. This work could not have been possible without the support of the owners and operators of the coastal power plants who funded the impingement surveys: Los Angeles Department of Water and Power, AES Redondo Beach, AES Alamitos, AES Huntington Beach, El Segundo Power, and Southern California Edison. We would like to thank the various staff members of MBC Applied Environmental Sciences from 2001 to 2007, who conducted these surveys during all hours. This manuscript benefited from the comments of D. Guthrie and three anonymous reviewers.

Literature Cited

Allen, L.G., A.M. Findlay, and C.M. Phalen. 2002. Structure and standing stock of the fish assemblages of San Diego Bay, California from 1994–1999. Bull. South. Calif. Acad. Sci., 101:49–85.

Allen, M.J. and K.T. Herbinson. 1990. Settlement of juvenile California halibut, *Paralichthys californicus*, along the coasts of Los Angeles, Orange, and San Diego Counties in 1989. Cal. Coop. Oceanic Fish. Invest. Rep., 31:84–96.

Cailliet, G.M., E.J. Burton, J.M. Cope, L.A. Kerr, R.J. Larson, R.N. Lea, D. Van Tresca, and E. Knaggs. 2000. Biological characteristics of nearshore fishes of California: a review of existing knowledge and proposed additional studies. http://www.dfg.ca.gov/marine/lifehistories/index.asp

Love, M.S., C.W. Mecklenburg, T.A. Mecklenburg, and L.K. Thorsteinson. 2005. Resource Inventory of Marine and Estuarine Fishes of the West Coast and Alaska: A Checklist of North Pacific and Arctic Ocean Species from Baja California to the Alaska-Yukon Border. U. S. Department of the Interior, U. S. Geological Survey, Biological Resources Division, Seattle, Washington, 98104, OCS Study MMS 2005-030 and USGS/NBII 2005-001.

———, M. Yoklavich, and L. Thorsteinson. 2002. The rockfishes of the northeast Pacific. UC Press, Los Angeles, California.

Miller, D.J. and R.N. Lea. 1972. Guide to the coastal marine fishes of California. Calif. Dep. Fish Game, Fish Bull. 157, 249 pp.

Pondella, D.J. II. and L.G. Allen. 2000. The nearshore fish assemblage of Santa Catalina Island. *In*: The Proceedings of the Fifth California Islands Symposium. (D.R. Browne, K.L. Mitchell, and H.W. Chaney, eds.) Santa Barbara Museum of Natural History, Santa Barbara, California. Pp. 394–400.

Accepted for publication 22 May 2008.

Bull. Southern California Acad. Sci.
107(3), 2008, pp. 187–188

INDEX TO VOLUME 107

Beck, D. Shane, see Miller, Eric F.
Bizzarro, Jospeh J. A Review of the Physical and Biological Characteristics of the Bahía Magdalena Lagoon Complex (Baja California Sur, Mexico). 1

Cooper, Daniel S., see Mathewson, Paul D.
Curtis, Michael D., see Miller, Eric F.

Dossett, Wayne, see Miller, Eric F.

Fierstine, Harry L. A Fossil Skull of the Extant Blue Marlin (*Makaira nigricans* Lacepède, 1802) from the Late Miocene of Orange County, California. 45
Franz, Karen, see Watanabe, Kayo

Gersberg, Richard M., see Watanabe, Kayo

Huddleston Richard W., see Takeuchi, Gary T.

Lei, Simon A. Impacts of Cotyledon Removal on Survival of Blackbrush (*Coleogyne ramosissima*: Rosaceae) Seedlings. 180

Markham, John C. New records of pseudionine bopyrid isopods, including two new species and one new genus, infesting porcellanid crabs (Decopoda: Anomura) on the Pacific coast of North and Central America. 144
Mathewson, Paul D., Stephanie N. Spehar, and Daniel S. Cooper. An Initial Carnivore Survey of Griffith Park, Los Angeles, California. 57
Metcalf, Anthony E., see Walker, George F.
Miller, Eric F. and Michael D. Curtis. First Occurrence of a Pacific Crevalle Jack, *Caranx caninus*, North of San Diego, California 41
Miller, Eric F., D., Shane Beck and Wayne Dossett. Length-Weight Relationships of Select Common Nearshore Southern California Marine Fishes. 185

Rodríguez-Santiago, Maria Amparo and Jorge Adrián Rosales-Casián. Abundance and Size Composition of Vermilion rockfish, *Sebastes miniatus* (Jordan and Gilbert 1880), from Sport Fishing Catches of San Quintin, Ensenada, Baja California, Mexico. 25
Rosales-Casián, Jorge Adrián, see Rodríguez-Santiago, Maria Amparo.

Spehar, Stephanie N., see Mathewson, Paul D.

Takeuchi, Gary T. and Richard W. Huddleston. A New Early Miocene Species of *Pogonias* (Teleostei: Sciaenidae) Based on Otoliths from California. 68

Walker, George F. and Anthony E. Metcalf. Genetic Variation in the Endangered *Astragalus jaegerianus* (Fabaceae, Papilionoideae): A Geographically Restricted Species. 160

Watanabe, Kayo, Karen Franz, and Richard M. Gersberg. Levels of the Organosphosphorus Pesticide Diazinon in the Chollas Creek Watershed, San Diego, CA, Since Its Phase-Out in 2004. 33

INSTRUCTIONS FOR AUTHORS

The BULLETIN is published three times each year (April, August, and December) and includes articles in English in any field of science with an emphasis on the southern California area. Manuscripts submitted for publication should contain results of original research, embrace sound principles of scientific investigation, and present data in a clear and concise manner. The current AIBS Style Manual for Biological Journals is recommended as a guide for contributors. Consult also recent issues of the BULLETIN.

MANUSCRIPT PREPARATION

[illegible]

PROCEDURE

[illegible]

INSTRUCTIONS FOR AUTHORS

The BULLETIN is published three times each year (April, August, and December) and includes articles in English in any field of science with **an emphasis on the southern California area**. Manuscripts submitted for publication should contain results of original research, embrace sound principles of scientific investigation, and present data in a clear and concise manner. The current AIBS *Style Manual for Biological Journals* is recommended as a guide for contributors. Consult also recent issues of the BULLETIN.

MANUSCRIPT PREPARATION

The author should submit at least two additional copies with the original, on 8½ × 11 opaque, nonerasable paper, double spacing the entire manuscript. Do not break words at right-hand margin anywhere in the manuscript. Footnotes should be avoided. **Manuscripts which do not conform to the style of the BULLETIN will be returned to the author.**

An abstract summarizing in concise terms the methods, findings, and implications discussed in the paper *must* accompany a *feature article. Abstract should not exceed 100 words.*

A feature article comprises approximately five to thirty typewritten pages. Papers should usually be divided into the following sections: abstract, introduction, methods, results, discussion and conclusions, acknowledgments, literature cited, tables, figure legend page, and figures. Avoid using more than two levels of subheadings.

A research note is usually one to six typewritten pages and rarely utilizes subheadings. Consult a recent issue of the BULLETIN for the format of *notes*. Abstracts are not used for notes.

Abbreviations: Use of abbreviations and symbols can be determined by inspection of a recent issue of the BULLETIN. **Omit periods after standard abbreviations:** 1.2 mm, 2 km, 30 cm, but Figs. 1–2. Use numerals *before* units of measurements: 5 ml, but nine spines (10 or numbers above, such as 13 spines). The metric system of weights and measurements should be used wherever possible.

Taxonomic procedures: Authors are advised to adhere to the taxonomic procedures as outlined in the International Code of Botanical Nomenclature (Lawjouw et al. 1956), the International Code of Nomenclature of Bacteria and Viruses (Buchanan et al. 1958), and the International Code of Zoological Nomenclature (Ride et al. 1985). Special attention should be given to the description of new taxa, designation of holotype, etc. Reference to new taxa in titles and abstracts should be avoided.

The literature cited: Entries for books and articles should take these forms.

McWilliams, K. L. 1970. Insect mimicry. Academic Press, vii+326 pp.

Holmes, T. Jr., and S. Speak.1971.Reproductive biology of Myotis lucifugus. J. Mamm., 54:452–458.

Brattstrom, B. H.1969.The Condor in California. Pp. 369–382 in Vertebrates of California. (S. E. Payne, ed.), Univ. California Press, xii+635 pp.

Tables should not repeat data in figures *(line drawings, graphs, or black and white photographs) or contained in the text.* The author must provide numbers and short legends for tables and figures and place reference to each of them in the text. Each table with legend must be on a separate sheet of paper. All figure legends should be placed together on a separate sheet. **Illustrations and lettering thereon should be of sufficient size and clarity to permit reduction to standard page size;** *ordinarily they* **should not exceed 8½ by 11 inches** in size and after final reduction lettering must equal or exceed the size of the typeset. All half-tone illustrations will have light screen (grey) backgrounds. Special handling such as dropout half-tones, special screens, etc., must be requested by and will be charged to authors. **As changes may be required after review, the authors should retain the original figures in their files until acceptance of the manuscript for publication.**

Assemble the manuscript as follows: cover page (with title, authors' names and addresses), abstract, introduction, methods, results, discussion, acknowledgements, literature cited, appendices, tables, figure legends, and figures.

A cover illustration pertaining to an article in the issue or one of general scientific interest will be printed on the cover of each issue. Such illustrations along with a brief caption should be sent to the Editor for review.

PROCEDURE

All manuscripts should be submitted to the Editor, Daniel A. Guthrie, W. M. Keck Science Center, 925 North Mills Avenue, Claremont, CA 91711. Manuscripts may be submitted by mail, or by e-mail to dguthrie@jsd.claremont.edu as a Word document. **Authors are requested to submit the names, addresses and specialities of three persons who are capable of reviewing the manuscript. Evaluation of a paper** submitted to the BULLETIN begins with a critical reading by the Editor; several referees also check the paper for scientific content, originality, and clarity of presentation. Judgments as to the acceptability of the paper and suggestions for enhancing it are sent to the author at which time he or she may be requested to rework portions of the paper considering these recommendations. The paper then is resubmitted on disk in word format and may be re-evaluated before final acceptance.

Proof: The galley proof and manuscript, as well as reprint order blanks, will be sent to the author. He or she should **promptly** and **carefully read** the proof sheets for errors and omissions in text, tables, illustrations, legends, and bibliographical references. He or she marks corrections on the galley (copy editing and proof procedures in *Style Manual*) and **promptly returns both galley and manuscript** to the Editor. Manuscripts and original illustrations will not be returned unless requested at this time. **All changes in galley proof attributable to the author (misspellings, inconsistent abbreviations, deviations from style, etc.) will be charged to the author. Reprint orders are placed with the printer, not the *Editor*.**

CONTENTS

Articles

New Records of Pseudionine Bopyrid Isopods, including two new Species and one new Genus, infesting Porcellanid Crabs (Decapoda: Anomura) on the Pacific coast of North and Central America. John C. Markham 145

Genetic Variation in the Endangered *Astragalus jaegerianus* (Fabaceae, Papilionoideae): A Geographically Restricted Species. George F. Walker and Anthony E. Metcalf 158

Research Notes

Impacts of Cotyledon Removal on Survival of Blackbrush (*Coleogyne ramosissima*: Rosaceae) Seedlings. Simon A. Lei 178

Length-Weight Relationships of Select Common Nearshore Southern California Marine Fishes. Eric F. Miller, D. Shane Beck, and Wayne Dossett 183

Index to Volume 107 187

Cover: *Aporobopyrus bourdonis*, new species. Drawing by John C. Markham. See page 147 for details.